SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors English **GRADE 10**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1- The Dystopia	RL9-10.1 RL9-10.2 RL9-10.3 RL9-10.4 RL9-10.5 RL9-10.6 RL9-10.10 SL9-10.1 SL9-10.4 SL91-10.6 W9-10.8 W9-10.9 W9-10.10 L9-10.1 L9-10.2 L9-10.3 L9-10.4 L9-10.5 L9-10.6	Essential Questions • What are the characteristics of a dystopian novel? • How is there "only one story" (Foster)? Texts "Contents of a Dead Man's Pocket" by Jack Finney *Fahrenheit 451* by Ray Bradbury *How to Read Literature Like a Professor* by Thomas C. Foster "The Lady, or the Tiger?" by Frank Stockton "The Devil and Tom Walker" by Washington Irving Content Specific Vocabulary dystopia, symbol, motif, figurative language, archetype, allusion, understatement, theme, Faustian bargain	Formative Short Answer reading quizzes Pre, during and post reading questions Summative Selection tests for short stories (multiple choice for comprehension, literary devices, a vocabulary section and an extended response) Unit test (character matching, multiple choice for comprehension, multiple choice for symbolism and figurative language) Performance Task Project Cube with various project options-mandatory minimum of one essay for the year

TEACHER'S NAME: Erin Bobby **6/17**

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CURRICULUM FRAMEWORK

COURSE: Honors English **GRADE 10**

Unit 2-The Autobiographical Novel	RL9-10.1 RL9-10.2 RL9-10.3 RL9-10.4 RL9-10.5 RL9-10.6 RL9-10.7 RL9-10.10 SL9-10.1 SL9-10.4 SL91-10.6 W9-10.8 W9-10.9 W9-10.10 L9-10.1 L9-10.2 L9-10.3 L9-10.4 L9-10.5 L9-10.6	Essential Questions • What distinguishes an autobiography from an autobiographical novel? • What literary devices are in an autobiographical novel that are not in an autobiography? Texts "I Know Why the Caged Bird Sings" by Paul Lawrence Dunbar "Caged Bird" by Maya Angelou *I know Why the Caged Bird Sings* by Maya Angelou Content Specific Vocabulary autobiography, autobiographical novel, figurative language, imagery, dialogue, dialect, motif, theme, coming of age	Formative Short answer and multiple choice reading quizzes Comprehension questions Write chapter of autobiographical novel Summative Unit test-AP level multiple choice close-reading questions; vocabulary ID and sentence construction Performance Task Project Cube-project options with mandatory minimum of one essay for the year Self Portrait Poster/Presentation (make collage about who they are, research two texts that portray interests, present board/two texts)

TEACHER'S NAME: Erin Bobby **6/17**

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COURSE: Honors English **GRADE 10**

Unit 3-The Coming o Age Novel	RL9-10.1 RL9-10.2 RL9-10.3 RL9-10.4 RL9-10.5 RL9-10.6 RL9-10.10 SL9-10.1 SL9-10.4 SL91-10.6 W9-10.8 W9-10.9 W9-10.10 L9-10.1 L9-10.2 L9-10.3 L9-10.4 L9-10.5 L9-10.6	Essential Questions • What are the characteristics of a Bildungsroman? • What is satire and how is it achieved? Texts *Huck Finn* by Mark Twain Content Specific Vocabulary Bildungsroman, allusion, dialect, hyperbole, irony, malapropism, paradox, satire, symbol, theme	Formative Short answer and multiple choice reading quizzes Comprehension questions Satirical cartoon picture Summative Unit test (multiple choice comprehension questions, vocabulary sentence completion, two essay questions, literary terminology exemplification and analysis) Performance Task Project Cube-project options with mandatory minimum of one essay a year
Unit 4-Tragedy and Theatre	RL9-10.1 RL9-10.2 RL9-10.3 RL9-10.4 RL9-10.5 RL9-10.6 RL9-10.7 RL9-10.10 SL9-10.1 SL9-10.4 SL91-10.6 W9-10.8 W9-10.9 W9-10.10 L9-10.1 L9-10.2 L9-10.3 L9-10.4 L9-10.5 L9-10.6	Essential Questions • What are the elements of a classic Greek and Shakespearean tragedy? • In a tragedy, what is the function of a soliloquy? Of poetry vs. prose? • How does a tragedy use dramatic irony to create tension, spark catharsis, and shape theme? • To what extent is a classic tragedy didactic? Texts *Oedipus Rex* by Sophocles *Hamlet* by Shakespeare	Formative Short answer and multiple choice reading quizzes Comprehension questions Summative Unit test on *Oedipus Rex* Unit test on *Hamlet* (AP level questions for close reading analysis; open ended short answer questions about tragic elements in *Oedipus Rex*)

TEACHER'S NAME: Erin Bobby **6/17**

		Content Specific Vocabulary Tragedy, tragic hero, tragic deed (hamartia), tragic flaw (including hubris), tragic end, catharsis, chorus, strophe, antistrophe, dramatic irony, situational irony, verbal irony, foil, meter, iambic pentameter, dialogue, monologue, soliloquy, couplet, blank verse, rhyme, stage directions, theme	Performance Task Literary analysis paper on *Hamlet* Presentation about elements of tragedy in *Oedipus Rex*

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CURRICULUM FRAMEWORK

COURSE: IB Literature HL **GRADE: 11/12**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Part 4: Works Freely Chosen *Note that each "Part" is a unit that takes approximately one semester to complete.	RL.11-12.1-10 W.11-12.1-6,10	Description: Students explore 3 works of the teacher's choosing (*The Curious Incident of the Dog in the Nighttime* by Mark Haddon, *The Kite Runner* by Khaled Hosseini, and *Wide Sargasso Sea* by Jean Rhys). Students experience works that are unusual in some way. Often, this part deals with texts that have unusual mediums, adaptations, qualities, or even narrators. In my version of this unit. I am focused on exploring different perspectives. In *Curious Incident*, we experience the perspective of an autistic boy; in *Kite Runner*, an Afghani boy; and in *Wide Sargasso Sea,* a Creole woman famously known as Bertha in Charlotte Bronte's *Jane Eyre*. Even though it is part of a later unit, students do read *Jane Eyre* before reading *Wide Sargasso Sea* since the former is the inspiration for the latter. Essential Questions • How does sentence structure help to shape a character and our understanding of him/her and his/her perspective? • How is the absence of figurative language just as meaningful as its presence? • How are symbols used to enhance or contribute to the meaning of the work as a whole? • What archetypes exist across works of varying styles? • How does the writer build realistic empathy for both the protagonist and antagonist?	Reading Quizzes (Summative) Class Discussions (Formative) Unit Test for *Curious Incident* (Summative) Practice Essays and AP Questions (Formative) Final IB Performance Assessment: Individual Oral Presentation (IOP) – Students prepare a 10-15 minute presentation that states and defends a literary arguent about some aspect of one or more of the Part 4 works. Students may work alone or with one partner. Each presentation is followed with approximately two minutes of follow-up/clarification questions from the teacher and/or other students in the class. Assessment is scored by the teacher with an IB Rubric.
Part 1: Works in Translation	RL.11-12.1-10 RI.11-12.7,9	Description: Students study 3 works that have been translated from another language into English (*The*	Translation Activities for "A Hunger Artist," *The Metamorphosis* and

*See detailed unit plan	W.11-12.1-2,4-10	*Metamorphosis* by Franz Kafka, *Oedipus Rex* by Sophocles, *A Doll's House* by Henrik Ibsen). This part considers what is lost and gained when a work is translated into another language. Students also explore cultural and contextual background for each work to consider how knowledge of that impacts one's understanding or appreciation of the work(s). All of the works I've selected for this part relate to the downfall of a character. Essential Questions • What is lost or changed when a work is translated? • What role does connotation play in our understanding of a character? How does that understanding impact the meaning of the work as a whole? • If understanding of language is dependent on one's indigenous understanding of culture and the connotations of words, to what extent can we ever know original intent? If one's understanding of connotations is also personal as well as cultural, how can one ever truly understand another? • In what ways do time and place matter to a work? • How does the understanding of cultural and contextual considerations of a work change one's understanding of that work? • Are there some characters in a work whose chief role is to convey cultural values? *Please note that as of School Year 2017-2018, *Oedipus Rex* will be replaced with *Kitchen* by Banana Yoshimoto	*Oedipus Rex* (formative) 3 Reading Quizzes for *The Metamorphosis* (summative) Dramatic Literary Terms Quiz (summative) Reading Questions for *Oedipus Rex* and *A Doll's House* (formative) Class Discussions (formative) Interactive Oral Presentations (formative) Interactive Orals (formative) Reflective Statements (formative) Supervised Writings (formative) Final IB Performance Assessment: Written Assignment (WA) – Students go through a five-step reflective and analytical process that includes presentations (I.O. Presentations), discussions (I.O.'s), reflective statements about the I.O.'s, and supervised writings about the works. This culminates in them selecting one work and developing their supervised writing for that work into a 1200 – 1500 word literary essay called the Written Assignment.

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CURRICULUM FRAMEWORK

COURSE: IB Literature HL **GRADE: 11/12**

			Assessment is scored by IB using the WA rubric.
Part 2: Close Reading	RL.11-12.1-10 RI.11-12.1-6,10 W.11-12.1-2,4-6,10	Description: Students study 3 works of three different genres, one of which has to be a collection of poems (*In Cold Blood* by Truman Capote, *Jane Eyre* by Charlotte Bronte, and poetry by Sylvia Plath). This part works on close reading skills and the recognition of author's craft. Aside from that, there is no uniting theme between these works. Essential Questions • How do the writer's choices of form, structure, technique, and style help to shape meaning? • How do the writer's choices pertaining to plot, character, and setting help to shape meaning?	Reading Quizzes (summative) Practice AP Questions about style and effect of author's choices (formative) Thesis writing (formative) Class discussions (formative) Practice IOCs (oral commentaries) (formative)

TEACHER'S NAME: Erin Bobby 6/17

			Final IB Performance Assessment: Individual Oral Commentary (IOC) – Students engaged in a 20-minute commentary/interview about 2 of the works in this part. They receive a poem that we've not studied in class (but one that is by the poet we've been studying). They receive 20 minutes to read, analyze and prepare an 8-minute commentary (informal presentation with no visuals) about the poem. They then present this commentary to their teacher and another scorer (note that this is not in front of the class). After 8 minutes, the teacher conducts a Question-Answer session about the poem in order to probe further into the student's analysis of the poem. The last 10 minutes of the interview consists of an interview/discussion between the teacher and the student about one of the other two works studied in Part 2 (either Capote or Bronte). The student has no knowledge beforehand which of the two remaining words will be discussed. The IOC is audio-recorded. The assessment is scored by the

			teacher using the IOC rubric and then moderated by IB.
Part 3: Genre Study	RL.11-12.1-10 W.11-12.1-2,4-6,10	Description: Students study 4 works of the same genre (we study dramas – *Pygmalion* by George Bernard Shaw, *Cat On A Hot Tin Roof* by Tennessee Williams, *The Importance of Being Earnest* by Oscar Wilde, and *The Crucible* by Arthur Miller). Students learn about the conventions of the genre being studied and compare and contrast them and their effects between the varying plays. Essential Questions • What are the most common conventions of drama? • What differentiates a tragedy from a comedy? • What differentiates a classic tragedy from a modern one? • What differentiates a classic comedy from a modern one? • How are some dramatic conventions used similarly across very different styles of plays? • How are some dramatic conventions used differently across very different styles of plays, and to what effect? Sample Paper 1 Questions:	Reading Questions (formative) Drama Terms Quiz (summative) Practice (mock) Paper 1 (summative) Practice (mock) Paper 2 (formative) Final IB Performance Assessment: Exams – Paper 1 & Paper 2 Paper 2 directly assesses Part 3: Students receive three prompts and have two hours to respond to one of them in an essay, using at least two of the Part 3 works studied.

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CURRICULUM FRAMEWORK

COURSE: IB Literature HL **GRADE: 11/12**

		• "Plays are meant to be seen and heard" is a common retort to those who only read a play. In light of this statement, compare how, and how effectively, at least two plays you have studied have made seeing and hearing indispensable to our experience and understanding of key moments in their plots. • Drama often heralds the underdog, providing the downtrodden a voice and, at times, even triumph. Compare how, and to what effect, at least two plays you have studied draw attention to the downtrodden figure. • In drama an exciting force (a key thought, action or event) works as a catalyst to begin the central conflict. Comparing at least two of the plays you have studied, what serves as the exciting force and how is it significant to the meaning of the play? • The words and deeds of a character may contradict or correspond to one another. In at least two plays you have studied compare the extent and effect of such contradiction and/or correspondence. • The purpose of comedy extends beyond laughter. Other than provoking laughter, compare the role of comedy in at least two plays you have studied. • Although drama often presents the illusion that what we see on stage is real life, some playwrights dispel that illusion. Compare the techniques used and effects achieved by at least two playwrights you have studied to make the audience aware that they are watching a play.	Paper 1 assesses all skills in IB Literature HL: Students receive a poem and a prose extract that they've never seen before. They choose one of the texts and write an analytical essay about it (in two hours' time). Note that there is no prompt for the essay. Both assessments are scored by IB using the Paper 1 and Paper 2 rubrics.

*More detailed information about the course as whole, including rubrics, etc. can be found at http://www.ibo.org/globalassets/publications/recognition/1_languagea_hl_2011.pdf and http://share.nanjing-school.com/dpextendedessay/files/2012/12/Languag-A-literature-npniqc.pdf.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Reading **GRADE: 6**

Unit	Standards	Unit Concept /Essential Questions	Assessments
CSET - Introduction	RL6.1 RL 6.10 RL 6.6 RL 6.4	Module 1 • What is a text based question? • How do I effectively answer a text based question? • How do I support a text based response with text evidence? Content Specific Vocabulary text based, text, passage, claim, tie-in, set-up, evidence, support, inferences, cite, quote, specific details, relevant details, elaboration	Quizzes – Formative Homework checks – Formatives Written CSET responses based on reading logs- formative Formative Sample Question What does the C in CSET represent? Describe the main character in your SSR book. Summative Sample Question Explain why the main character in the passage committed the crime. Summative Performance Task Sample Question After reading the assigned passages, use evidence from both passages to describe how the main characters were successful in their tasks.
Proverbs	RL 6.4 RL 6.10 RL 6.1	Module 1 • What is a proverb? • How can I determine what a proverb means? • How can I apply proverbs and their meanings to real life situations? • How can understanding proverbs help me understand what I read?	Homework checks- formative Classroom discussion – formative Tests - Summative

TEACHER'S NAME: Karen Willey **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Reading **GRADE: 6**

		Content Specific Vocabulary proverb, literal meaning, figurative meaning, definition, relationship, mental image, metaphor, illustrate, tone, connotation, denotation	Formative Sample Question Classroom discussion of proverb definitions/homework Summative Sample Question Explain the following proverb: "You cannot shake hands with a clenched fist."
Reading Logs	RL 6.1 RL 6.2 RL 6.3 RL 6.6 RL 6.10	Module 1 • How many minutes did I read this week? • What genres am I interested in and how can I determine this? • How can I support my analysis of my book with text based evidence? Content Specific Vocabulary genre, character traits, elements of fiction, setting, plot, point of view, theme, character, signature	Completed reading logs – formative Summative Sample Question CSET response – How does the author use events in the story to move the plot forward? Summative Performance Task Sample Question Using your completed reading logs from the entire school year, collect data on what your favorite genre is. Explain why you believe this genre would be considered your favorite. Use evidence from your reading logs as well as information from your INB to support your explanation.
Fiction Studies	RL 6.1 RL 6.2 RL 6.3 RL 6.4 RL 6.5	Module 1- Short Stories • What is fiction? • How is a story classified in terms of genre? • How do I effectively understand what I am reading?	Homework/Classwork - Formative Quizzes- Formative

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CURRICULUM FRAMEWORK

COURSE: Reading **GRADE: 6**

	RL 6.6 RL 6.7 RL 6.9 RL 6.10	Module 2 – Novel Studies • How do the elements of fiction apply to a longer piece of text? • How does active reading enhance my understanding of a novel? • How can I annotate text to assist my understanding of what I am reading? Content Specific Vocabulary genre, realistic fiction, historical fiction, science fiction, mystery, action/adventure, elements of fiction, conflict, point of view, internal/external conflict, types of conflict (man vs man, man vs self, man vs, nature, man vs society) plot, rising action, falling action, climax, resolution, theme, viewpoint, tone, logical sequence of events, context clues	Formative Sample Question Explain why a particular passage would be classified as fiction. Which subgenre would this passage be classified as? Explain how the events of the novel work together to enhance the reader's understanding of the characters. Summative Sample Question Describe how the relationship between the elements of fiction of a particular novel moves the story forward. Summative Performance Task Sample Question
Nonfiction Studies	RI 6.1 RI 6.2 RI 6.3 RI 6.4 RI 6.5 RI 6.6 RI 6.7 RI 6.10	Module 1- Nonfiction Passages • What is nonfiction? • How is nonfiction different than fiction? • How do I approach reading nonfiction to ensure I understand what I am reading? Content Specific Vocabulary nonfiction, text structure, text features, captions, illustrations, graph, table, purpose, claims, central idea, technical text, anecdote, point of view, trace, evaluate,	Homework/Classwork - Formative Formative Sample Question How do the text features used in this passage increase the reader's understanding of the material the author is presenting? Summative Sample Question Cite one piece of evidence from the text that supports the author's view on the use of uniforms

			in schools. Summative Performance Task Sample Question After reading the three passages, write a narrative as if you were a spy. Include information from all three passages to support your ideas.
Poetry	RL 6.1 RL 6.2 RL 6.4 RL 6.5 RL 6.6 RL 6.7 RL 6.8	Module 1: • What is poetry? • How is poetry different than regular writing? • How can I increase my understanding of poetry when I read it? Content Specific Vocabulary poem, stanza, line, form, free verse, blank verse, haiku, irony, alliteration, rhythm, repetition, mood, tone, theme, syllables, personification, symbol, prose, verse	Homework/Classwork- Formative Formative Sample Question Identify the type of poem. Cite evidence to support your response. Summative Sample Question How did the poet's use of rhyme affect the tone of this poem? Summative Performance Task Sample Question How did the poet's use of rhyme affect the tone of this poem?

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Reading **GRADE: 6**

TEACHER'S NAME: Karen Willey **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Research and Writing **GRADE 11**

Unit	Standards	Unit Concept /Essential Questions	Assessments
Course Overview	AASL Standard 1: Inquire, think critically, and gain knowledge 1.1.2 Use prior and background knowledge as context for new learning 1.1.9 Collaborate with others to broaden and deepen understanding. 1.4.2 Use interaction with and feedback from teachers and peers to guide own inquiry process AASL Standard 4: Pursue personal and aesthetic growth. 4.4.1 Identify own areas of interest	Focus of Writing and Research course Students' Backgrounds as Assets Class Policies and Procedures Accountability Agenda Seating Inventory Essential Question • How can I be a successful student?	FORMATIVE: Post-It Note Introduction Activity (name, nickname, favorite subject, IB trait, college hope to attend) Seating Inventory Introduction to Class Policies and Procedures Most Important Rule Writing Piece Choose a future career, a college that you would like to attend, and list five traits that you feel that you possess.
Formatting and Supporting Evidence	AASL Standard 1: Inquire, think critically, and gain knowledge. 1.2.2 Demonstrate confidence and self-direction by making independent choices in the selection of resources and information. 1.2.5 Demonstrate adaptability by changing the inquiry focus, questions, resources, or strategies when necessary to achieve success. AASL Standard 2: Draw conclusions, make informed decisions, apply knowledge to new situations and create new knowledge 2.1.3 Use strategies to draw conclusions from information and apply knowledge to curricular areas, real world situations, and further investigations AASL Standard 3: Share knowledge and participate ethically and	MLA Format CSET Importance of Developing a Claim and Supporting It Reading Others Extended Essays-Find Strengths and Pitfalls Asking Research Questions-Where to Begin Reading Up on Research Question Outlining Headings for Research Question Creating Notes on Resources for Bibliography Cons of Citation Machine Essential Question • Why is it important to have valid evidence in writing?	FORMATIVE: Brainstorm for Writing Assignment-Choose a future career, a college that you would like to attend, and list five traits that you feel that you possess. Writing Assignment-Pretend that you are a 12th grade teacher at SAAS, write a recommendation letter for one of your 12th grade students in

TEACHER'S NAME: Jen Leonard **6/17**

	productively as members of our democratic society 3.2.2 Show social responsibility by participating actively with others in learning situations and by contributing questions and ideas during group discussions. AASL Standard 4: Pursue personal and aesthetic growth. 4.1.5 Connect ideas to own interests and previous knowledge and experience.		the course (write a claim and back it up). Discussion-importance of becoming a good writer and writing a good argument. Read and Discuss Extended Essay/Partners Gather to Discuss Strengths and Pitfalls of Essays Use Bibliography Note Pages *Writing a Research Paper* Exercise 1 page 11 *Writing a Research Paper* Exercise 2 page 13 *Writing a Research Paper* Exercise 3 page 14 *Writing a Research Paper* Exercise 4 p.15-17 *Writing a Research Paper* Exercise 8 page 19 *Writing a Research Paper* Exercise 9 page 19 SUMMATIVE: Pre-test on Schoology
Sources	AASL Standard 1: Inquire, think critically, and gain knowledge. 1.1.8 Demonstrate mastery of technology tools for accessing	Types of Sources-Primary and Secondary Locating Reliable Resources	FORMATIVE: Gallery Walk of Reliable and

	information and pursuing inquiry. 1.2.3 Demonstrate creativity by using multiple resources and formats. 1.2.4 Maintain a critical stance by questioning the validity and accuracy of all information AASL Standard 4: Pursue personal and aesthetic growth. 4.1.4 Seek information for personal learning in a variety of formats and genres.	Criteria Evaluating Sources-Partners Choosing a Topic and Locating Reliable Resources (Time etc.) Essential Question • Why is it necessary to use reliable resources?	Unreliable Resources Prezi on Finding Reliable Websites Students will work through the assigned websites to determine if they are reliable or unreliable. Students will use a checklist and will write a reflection/online blog on the websites. Exit Ticket-What makes a website reliable? *Writing a Research Paper* Exercise 1 page 25 *Writing a Research Paper* Exercise 2 page 26 *Writing a Research Paper* Exercise 3 page 26 *Writing a Research Paper* Exercise 5 page 27 SUMMATIVE: Primary and Secondary Source Quiz
Advanced Searching	AASL Standard 1: Inquire, think critically, and gain knowledge. 1.2.6 Display emotional resilience by persisting in information searching despite challenges.	Using Advanced Search Features UD Lib Search PowerSearch	FORMATIVE: Musical Share of What was Located on UD Lib Search

	1.2.7 Display persistence by continuing to pursue information to gain a broad perspective.	Essential Question • What advantages do writers have when they use advanced search features and UD lib searches?	(Write down one positive and one I wonder)
Taking Notes	AASL Standard 1: Inquire, think critically, and gain knowledge. 1.3.1 Respect copyright/intellectual property rights of creators and producers. 1.3.3 Follow ethical and legal guidelines in gathering and using information. AASL Standard 2: Draw conclusions, make informed decisions, apply knowledge to new situations, and create new knowledge. 2.1.2 Organize knowledge so that it is useful. 2.1.4 Use technology and other information tools to analyze and organize information. AASL Standard 1: Inquire, think critically, and gain knowledge. 1.3.1 Respect copyright/intellectual property rights of creators and producers. 1.3.3 Follow ethical and legal guidelines in gathering and using information.	Cornell Note-Taking Plagiarism vs. Paraphrase Note-Taking Using Cornell Notes Assessment on Reliable vs. Unreliable Paraphrasing vs. Paraphrasing Note-Taking • Why is it important to paraphrase information while researching? • Why is note-taking such a powerful tool?	FORMATIVE: Cornell Notes PPT-Note-Taking Activity Researching Topic and Note-Taking using Cornell Notes Note-Taking PowerPoint Students read various sample IB EE portions and decide if they sample piece if an example of plagiarism or paraphrasing and give reasoning. They can write a response using C-SET. UD Lib (and use Internet) Assessment on Schoology. Write a Google Doc Argumentative Collaborative Piece *Writing a Research Paper* Exercise 7 page 51 *Writing a Research Paper* Exercise 6 page 61
Components of a Research	AASL Standard 2: Draw conclusions, make informed decisions, apply knowledge to new situations and create new knowledge.	-Purdue Owl Introduction -MLA	FORMATIVE: Explore Purdue Owl

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Research and Writing **GRADE 11**

Paper in Relation to IB Extended Essay Guide	2.1.1 Continue an inquiry-based research process by applying critical-thinking skills (analysis, synthesis, evaluation, organization) to information and knowledge in order to construct new understandings, draw conclusions, and create new knowledge. 2.1.6 Use the writing process, media, and visual literacy, and technology skills to create products that express new understandings. 4.1.2 Read widely and fluently to make connections with self, the world, and previous reading. AASL Standard 3: Share knowledge and participate ethically and productively as members of our democratic society. 3.2.3 Demonstrate teamwork by working productively with others. AASL Standard 4: Pursue personal and aesthetic growth. 4.1.2 Read widely and fluently to make connections with self, the world, and previous reading.	-Creating a Title Page and Header -Acknowledgements -Creating a Table of Contents -Create a Working Outline -Creating a Bibliography -Choose Topic based on Interest -Conduct Research -Note Taking on index cards -Need for In-Text Citations -Conduct Research Essential Question • How does MLA serve as a writer's guide during the writing process?	Write a Google Doc argumentative collaborative piece *Writing a Research Paper* Exercise 1 page 43 *Writing a Research Paper* Exercise 8 page 63-64 *Writing a Research Paper* Exercise 10 page 39 *Writing a Research Paper* Exercise 11 page 39 *Writing a Research Paper* Exercise 12-13 page 40-41 Contract for Extended Essay WS 43 Complete Tentative Topic WS 41 Begin research using databases Note card check #1 Note taking on note cards Continue research using databases Note card check #2 Extended Essay Contract WS 43 *Writing a Research Paper*

TEACHER'S NAME: Jen Leonard **6/17**

			Exercise 4 page 48 *Writing a Research Paper* Exercise 1 page 100 SUMMATIVE: IB EE Guide Quiz
Formulating a Research Question	AASL Standard 3: Share knowledge and participate ethically and productively as members of our democratic society. 3.2.1 Demonstrate leadership and confidence by presenting ideas to others in both formal and informal situations. AASL Standard 4: Pursue personal and aesthetic growth. 4.1.6 Organize personal knowledge in a way that can be called upon easily.	Formulating Essay Question Topic Map and Outline Thesis Statement Essential Question • Why is it necessary to formulate a research question that is limited?	FORMATIVE: Formulating Essay Question WS 44-47 Topic Map and Outline WS 48-51 Collaborative Share with Group on Topic and Thesis Statement Outline Due *Writing a Research Paper* Exercise 5-6 page 75-76 *Writing a Research Paper* Exercise 3 page 57 *Writing a Research Paper* Exercise 5-6 page 75-76
Writing Process	AASL Standard 2: Draw conclusions, make informed decisions, apply knowledge to new situations and create new knowledge. 2.1.5 Collaborate with others to exchange ideas, develop new understandings, make decisions, and solve problems. 2.1.6 Use the writing process, media, and visual literacy, and technology skills to create products that express new understandings.	Argumentative Writing In Text Citations Writing an Introduction Writing Process Footnotes Conferencing on Draft #1	FORMATIVE: *Writing a Research Paper* Exercise 3 page 82 *Writing a Research Paper* Exercise 3 page 102-103 Composing Draft #1

	AASL Standard 3: Share knowledge and participate ethically and productively as members of our democratic society. 3.1.3 Use writing and speaking skills to communicate new understandings effectively.	Writing Process Writing an Appendix Writing Process Essential Question • How does MLA serve as a writer's guide during the writing process?	*Writing a Research Paper* Exercise 10 page 93-94 *Writing a Research Paper* Editing Sheet p.123 Written Reflection on Draft #1 Editing/Revising Draft Composing Draft #2
Revising and Reflecting on Writing	AASL Standard 1: Inquire, think critically and gain knowledge 1.1.3 Develop and refine a range of questions to frame the search for new understanding AASL Standard 2: Draw conclusions, make informed decisions, apply knowledge to new situations and create new knowledge. 2.1.6 Use the writing process, media, and visual literacy, and technology skills to create products that express new understandings. 2.4.2 Reflect on systematic process, and assess for completeness of investigation 2.4.4 Develop directions for future investigations. AASL Standard 3: Share knowledge and participate ethically and productively as members of our democratic society. 3.1.3 Use writing and speaking skills to communicate new understandings effectively. AASL Standard 4: Pursue personal and aesthetic growth. AASL Standard 4: Pursue personal and aesthetic growth. 4.1.8 Use creative and artistic formats to express personal learning. 4.3.1 Participate in the social exchange of ideas, both electronically and in person.	Conferencing on Draft #2 Writing Process Writing an Abstract Composing Draft #3 Writing Process Selecting a Topic/Research Question for Extended Essay (IB Assignment) Class Review Writing Process Reflection on Writing Process Celebrating Published Writing Essential Question • Why is it necessary for a writer to reflect on his/her writing?	FORMATIVE: Plan of Action WS 88 Written Reflection on Draft #2 Editing/Revising Draft Written Reflection on Draft #3 Checklist on Extended Essay MLA Post-Test on Schoology Composing Draft #4 Written Reflection on Research and Writing Process Presentations of Published Writing SUMMATIVE: Extended Essay Practice (Rubric Scored) Extended Essay for IB (IB Rubric Scored)

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Writing **GRADE: 6**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Narrative Writing	W 6.3, 6.4, 6.5, 6.10 L 6.1, 6.2, 6.3, 6.5 SL 6.5, 6.6	Essential Questions • How will the writer convey the importance of the story/essay to the reader? • How do writers reveal themselves when constructing narrative pieces? • How did coming to SAAS change the narrator? • How do writers utilize figurative language/sensory language to enhance a narrative? • What tools do writers use to be descriptive? Content Specific Vocabulary Attention Getting Lead, Bridge, Thesis, Elaboration, Conclusion, Zinger, Literary Devices, Transitions, Showing Details, Sensory Language, Figurative Language, Outline, Chronological Order, AGL Strategies, 6 plus 1 Traits of Writing	Lesson Quizzes- Formative Daily Journal Writing-Formative Figurative Language Booklet-Summative Performance Task Essay - Summative Formative Sample Write a paragraph describing your day at the beach. Use a simile. Summative Sample You have been asked to bring in three personal possessions that will help the class get to know you better. Write a speech to the class introducing yourself and your items.
Informative Writing	W 6.2, 6.4, 6.5, 6.7, 6.8, 6.9, 6.10 L 6.1, 6.2, 6.4, 6.6 SL 6.2, 6.4, 6.5, 6.6	Essential Questions • How do writers demonstrate an understanding of content when constructing an informative piece? • How do writers determine which text details to use to develop their ideas? • How do writers develop an introduction and conclusion for a text-based writing essay?	Daily Text Based Journal Writing-Formative Teacher feedback on written assignments-Formative Transition Super Hero - Summative Essay - Summative

TEACHER'S NAME: Kathy Kay **6/17**

		Content Specific Vocabulary Skinny Introduction, Skinny Conclusion, Transition, Transitional Phrases, Claim, Evidence	Formative Sample Students have to list 30 transitions from memory and spell them correctly. Summative Sample Using information from Scope magazines, write an informative essay explaining how food waste has become a large issue in the United States and solutions to reduce it.
Argumentative Writing	W 6.1, 6.4, 6.5, 6.7, 6.8, 6.9, 6.10 L 6.1, 6.2 SL 6.1, 6.2, 6.3, 6.4, 6.5, 6.6	Essential Questions • How do writers demonstrate an understanding of audience when constructing an argumentative piece? • How do writers determine relevant facts to support a claim using multiple sources? • How do writers distinguish which facts support a claim and which do not? Content Specific Vocabulary Credible Source, Claim, Evidence, Opposing View, Compare, Contrast, Call to Action,	Argumentative Daily Journal Writing-Formative Teacher-student Conferences-Formative Essay on Controversial topic-Summative Formative Sample Using the text provided, should texting while walking laws be enforced? (Paragraph) Summative Sample Write an argumentative essay in favor of or opposing the role of uniforms in school.

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CURRICULUM FRAMEWORK

COURSE: Writing **GRADE: 6**

Language	L 6.1, L6.2, L6.3, L6.4, L6.5, L 6.6	Essential Questions • How do writers correctly use pronouns in writing? • How do writers correctly use subject/verb agreement? • How are commas used in punctuating items in a series, multiple adjectives, and introductory material? Content Specific Vocabulary Pronouns, Subject, Verb, Adjective, Adverb, Preposition, Antecedent, Comma, Fragment, Run-on sentences, Sentence, Incomplete Sentence,	Correct Spelling in Daily Journal Writing- Formative Lesson Quiz on Sub/Verb- Formative Pronoun Test- Summative Comma Test- Summative Formative Sample Write a paragraph describing your favorite food. Use correct spelling Summative Sample Identify the subject, verb, and prepositional phrase in the following sentence: Please put this check into my bag.

TEACHER'S NAME: Kathy Kay **6/17**

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CURRICULUM FRAMEWORK

COURSE: Writing **GRADE: 7**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Narrative Writing	W 7.3, 7.4, 7.5, 7.6, 7.10 L 7.1, 7.2, 7.3, 7.5 SL 7.5, 7.6	Key Concept Writers understand a personal narrative as an important story/reflection from the writer's life/perspective. Essential Questions • How will the writer convey the importance of the story/essay to the reader? • How do writers reveal themselves when constructing narrative pieces? • How did this experience affect or change the narrator? Content Specific Vocabulary Ideas, Organization, Word choice, Voice, Conventions, Figurative language, Sensory language, Dialogue	Formative Assessments • Daily Journals • Quizzes • Exit tickets • Individual check-ins with students • Verbal and written feedback during writing process (organizers, wiki posts, rough drafts, etc.) Formative Assessment Sample In your journal, write a paragraph using sensory and figurative language about an event in your life. Summative Assessment Samples Write an essay describing the events of your summer. Include a Powerpoint/slideshow. Write an essay based on a personal experience that changed you. Include sensory and figurative language, description, and dialogue.

TEACHER'S NAME: Karen Hugues **6/17**

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CURRICULUM FRAMEWORK

COURSE: Writing **GRADE: 7**

Informative Writing	W 7.2, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10 L 7.1, 7.2, 7.4, 7.6 SL 7.2, 7.4, 7.5, 7.6	Key Concept Writers understand that an explanatory/informative text provides details, examples, and images that develop and support the thesis. Essential Questions • How do writers demonstrate an understanding of content when constructing an informative piece? • How well did you do in writing last marking period? Content Specific Vocabulary Ideas, Organization, Sentence Fluency, Conventions, Topic sentence, Transitions, Rollover sentence, Concluding sentence, Detail, Subdetail, Evidence, Explanation, Example	Formative Assessments • Daily Journals • Quizzes • Exit tickets • Individual check-ins with students • Verbal and written feedback during writing process (organizers, wiki posts, rough drafts, etc.) Formative Assessment Samples In your journal, write a paragraph explaining how you did on one writing assignment last marking period. On the class wiki, list the topics of the body paragraphs for your poaching article. Performance Task Essay After reading both Scope articles and watching the related video, write an article explaining the problem of poaching and what can be done to stop it. Summative Assessment Samples

			Write a reflection on your progress in writing. Focus on what you have learned, areas of strength and areas for improvement. Include evidence, examples and explanations. Write an explanatory essay on an approved topic of your choice. Begin with journal questions and conduct research to find the answer.
Argumentative Writing	W 7.1, 7.4, 7.5, 7.6, 7.8, 7.9, 7.10 L 7.1, 7.2 SL 7.7.1, 7.2, 7.3, 7.4, 7.5, 7.6	Key Concept Writers understand argumentative pieces provide a series of clear arguments or reasons to support claims. Essential Questions • How do writers demonstrate an understanding of audience when constructing an argumentative piece? • What will be your audience's greatest reservation to your argument and how will you address it? Content Specific Vocabulary Ideas, Organization, Word choice, Sentence Fluency, Voice, Conventions, CSET (Claim, Set up, Evidence, Tie-in), Counter claim, Refutation, AGL (attention getting lead) strategy, Conclusion strategy	Formative Assessments • Daily Journals • Quizzes • Exit tickets • Individual check-ins with students • Verbal and written feedback during writing process (organizers, wiki posts, rough drafts, etc.) Formative Sample On the class wiki, post your counterclaim and refutation on whether or not zoos should still exist. Provide meaningful feedback to at least two other writers.

			Summative Assessment Samples Write an argumentative letter on whether or not there should still be zoos. Write an argumentative article on whether or not zeppelins can regain their popularity. Create and film a public service announcement on a topic of choice (parent approved). In the credits, cite sources for your research.
Language	L 7.1, 7.2, 7.3, 7.4, 7.5, 7.6	Key Concept Writers understand shifts in verb tense, vague, ambiguous or unclear pronoun references, shifts in pronoun person or number, and dangling or misplaced modifiers. Essential Questions • How do writers correctly use spelling in writing? • How do writers correctly use verbs in writing? • How do writers correctly use pronouns in writing? • How do writers correctly use modifiers in writing?	Formative Assessments • Daily journals • Quizzes • Individual Check-ins Formative Assessment Sample In your journal, write a paragraph about your spring break being sure to use

		Content Specific Vocabulary Conventions, Verb tense , Pronouns , Antecedents , Dangling modifiers , Misplaced modifiers	correct spelling. Include frequently confused words (there, their, they're, etc.) Summative Assessment Samples Test on unclear pronoun references Test on misplaced and dangling modifiers

Curriculum Articulation Document | Content: 8th Grade Writing

	Grade 6	Grade 7	Grade 8
Unit One- Informative Writing - Essay			Writers how narrative elements can enhance informative/explanatory writing Writers understand and convey the importance and privilege of living in the U.S.
Unit focus			Engage and orient the reader by establishing a context and point of view. Use narrative techniques such as dialogue, pacing, description and reflection to develop an experience, event or character.
Essential Questions			How can I write an effective essay with relevant, specific details? How can I use a variety of narrative techniques such as dialogue, pacing, and figurative language to enhance my writing piece?
Texts			
Assessments Formative			• Daily writing and revision work focusing on personal experiences as an American • Daily proofreading

			exercises • Teacher observation of whole class, individual, and collaborative work sessions • Individual conferences with students during the writing process
Assessments Formative			• Using rubrics, checklists, feedback post it, and conference logs • Feedback on organizers and rough drafts
Assessments Summative			• Write an essay on the theme of Patriotism Work with your classmates to strengthen your writing through planning, revising, and editing your work. Submit your essay to the Patriot's Pen Writing Contest sponsored by the VFW.

Components to consider:

- What standards are taught? (Must identify CCSC where applicable and content standard where applicable)
- What is the focus of the unit of student?
- What are the essential questions?
- What are the text reading opportunities?
- What are the writing opportunities?
- What are the speaking and listening opportunities?
- What are the research opportunities?
- How are you going to use the same vocabulary in your document?
- What assessments will you give evidence of? (Formative, summative, and Performance Task) - Must give at least 3 formative, 1 summative for each unit. Must give at least 1 Performance task per year.

How are you going to identify those contents and assessments that you use across the content ?

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: 6**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1 **Fitness gram/ Physical Fitness**	3 4 6	**Personal Fitness Level** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format - Formative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and holds the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position

TEACHER'S NAME: Stephanie Hartsoe **6/17**

			in a controlled manner. Allow two trials, record the highest score.
	3 4 6	**FITT Principle** • What is the importance of being physically active? • Hoe does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Fitness components, cardiovascular endurance, muscular strength and muscular endurance, flexibility, body compositions, frequency, intensity, time and type.	F.I.T.T. Group discussion – Formative Example: Sally wants to be able to run a mile. Thinking about F.I.T.T (frequency, intensity, time, and type) what should Sally do to help her be able to run a mile? Students generate a few fitness plan for Sally.
	2 5	**Track and Field** What are the concept, principles, strategies and tactics used in physical activity? What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Hurdles, dash, sprint, jump, distance, relays, shot put, long jump	Group discussion - Formative Example: Which activities help with cardiovascular endurance? Which ones help with muscular strength?
Unit 2	1 2	**Sport 1: Diamond Games: Softball, kickball, Baseball** • What ways can I use physical activities throughout my life?	Game play – Summative

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: 6**

Using Sports to stay active	**5**	• What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Pitcher, catcher, baseman, short stop, outfielder, homerun, double play, strike zone, fair, foul, over throw, error, inning, walk	Example: Teacher observes for proper technique in throwing the ball to teammates.
	2 5	**Sport 2: Floor Hockey** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Forward, defenseman, rover, goalie, puck, penalty, foul, rebound, hat trick, assist, goalie box	Group discussion - Formative Example: Can playing floor hockey on the weekend for a few hours be beneficial? How? Explain using key terms from other units to help answer the question. - Looking for F.I.T.T
	2 **5**	**Volleyball** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary**	Group discussion -Formative

<table>
<tr><td></td><td></td><td>Serve, bump, set, spike, ace, rotate, fault, underhand, overhead, assist, block, back row, carry, dig, double hit, foul, front row, lift, pass, rally scoring, side out</td><td>Example: You want to improve your strength to serve the ball over the net. What are two activities you can do to help you? Explain how the activity is beneficial to the volleyball serve.</td></tr>
<tr><td></td><td>1
2
5</td><td>Basketball
What ways can I use physical activities throughout my life?
What are the concept, principles, strategies and tactics used in physical activity?
What are the personal and social behavioral expectations in physical settings?
Content Specific Vocabulary
Dribble, chest pass, bounce pass, lay up, double dribble, point guard, shooting guard, small forward, power forward, center, zone defense, man-to-man defense</td><td>Basketball checklist assessment – Formative

Example: ____Can pass and catch the ball.

_____Can dribble with the dominant hand. – students check off if partner can.

Game play – Summative

Example: Teacher observation for proper technique in dribbling skill.</td></tr>
<tr><td></td><td>2
5</td><td>Team handball
What are the concept, principles, strategies and tactics used in physical activity?
What are the personal and social behavioral expectations in physical settings?
Content Specific Vocabulary
Jump pass, overhand pass, wrist pass, catching, passive play, throw off, dribble</td><td>Group discussion – Formative

Example: Team handball is a game that combines many other skills from other</td></tr>
</table>

			games. How does playing this game help improve ones overall fitness? Student's response should talk about muscular endurance and strength in different muscle groups. (Upper body and lower body.)
	2 5	**Soccer** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, header, throw in, corner kick, striker, forward, defense, goalie, direct free kick, indirect free kick, touch line, goal line, goal kick, off sides	Quiz- Summative Example: Basic skills used in soccer are: a. kicking, b. dribbling, c. trapping, d. all of the above.
	1 2 5	**Ultimate Frisbee** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Frisbee, stall, end zone, touch down, sidelines, marking, count, pull	Group discussion- Formative Example: Fitness and sports are important to everyone's health. Is there away we can modify the game so we

			can include kids with disabilities? (Wheel chair, blind, deaf? – Students responses should come up with different modifications and how can do other games as well.
Unit 3 **Striking implement games – cooperation, sportsmanship**	**2** **5** **1** **2** **5** **6**	**Sport 1: Table Tennis** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault **Sport 2: Tennis/Pickle ball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? • What makes physical activity meaningful? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault, foot fault	Group discussion- Formative Example: What is sportsmanship? How can we show good sportsmanship in games? – Students responses should talk about positive speak, following the rules, handshake. Group discussion – Formative Example: What does cooperation mean? We are playing games where you have a partner. How can we show good cooperation? Student responses should talk about listening to teammate, working together to win, sportsmanship. Game Play – Summative Example: Teacher observation for

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	2 5	**Badminton** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Birdie, racquet, lob, drop, drive, swings: underhand, overhead, side arm	proper technique in serving the ball. Game play- Formative Example: Teacher observation looking for proper technique in forehand hit.
Unit 4 Aquatics	1 2 5	**Basic Swim skills** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Lane rope, Starting blocks, dive, free style, butterfly, backstroke, breaststroke, float, treading water, life ring, life guard, first aid, flutter kick, dolphin dive	Swim each stroke – Summative Example: Teacher observes for proper technique in stroke.
Unit 5 Fitness gram/ Physical Fitness	3 4 6	**Personal Fitness Level - Post** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format - Summative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the

			mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position in a controlled manner. Allow two trials, record the highest score.

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: 7**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1 **Fitness gram/ Physical Fitness**	3 4 6	**Personal Fitness Level** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format - Formative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the

			student returns to the starting position in a controlled manner. Allow two trials, record the highest score.
	3 4 6	**FITT Principle** • What is the importance of being physically active? • Hoe does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Fitness components, cardiovascular endurance, muscular strength and muscular endurance, flexibility, body compositions, frequency, intensity, time and type.	F.I.T.T. Group discussion – Formative Example: Using your scores on the FitnessGram. Lets pick an area and go over some ways to help improve our score. Students responses will put together workout plans.
	2 5	**Track and Field** What are the concept, principles, strategies and tactics used in physical activity? What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Hurdles, dash, sprint, jump, distance, relays, shot put, long jump	Group discussion - Formative Example: Which activities help with cardiovascular endurance? Which ones help with muscular strength? Skill performance – Summative Example- Teacher observation for proper technique.

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: 7**

Unit 2 **Using Sports to stay active**	**1** **2** **5**	**Sport 1: Diamond Games: Softball, kickball, Baseball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Pitcher, catcher, baseman, short stop, outfielder, homerun, double play, strike zone, fair, foul, over throw, error, inning, walk	Game play – Summative Example: Teacher observes for proper technique in game situations.
	2 **5**	**Sport 2: Floor Hockey** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Forward, defenseman, rover, goalie, puck, penalty, foul, rebound, hat trick, assist, goalie box	Group discussion - Formative Example: Can playing floor hockey on the weekend for a few hours be beneficial? How? Explain using key terms from other units to help answer the question. - Looking for F.I.T.T Game play – Summative Example: Teacher observes for proper technique in game situations

	2 **5**	**Volleyball** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, bump, set, spike, ace, rotate, fault, underhand, overhead, assist, block, back row, carry, dig, double hit, foul, front row, lift, pass, rally scoring, side out	Group discussion -Formative Example: You want to have more stamina to play longer. What are two activities you can do to help you? Explain how the activity is beneficial to your health. Game play – Summative Example: Teacher observes for proper technique in game situations
	1 **2** **5**	**Basketball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, chest pass, bounce pass, lay up, double dribble, point guard, shooting guard, small forward, power forward, center, zone defense, man-to-man defense	Game play – Summative Example: Teacher observation for proper technique in dribbling skill.

	2 5	**Team handball** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Jump pass, overhand pass, wrist pass, catching, passive play, throw off, dribble	Group discussion – Formative Example: Team handball is a game that combines many other skills from other games. How does playing this game help improve ones overall fitness? Student's response should talk about muscular endurance and strength in different muscle groups. (Upper body and lower body.) Game play – Summative Example: Teacher observes for proper technique in game situations
	2 5	**Soccer** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, header, throw in, corner kick, striker, forward, defense, goalie, direct free kick, indirect free kick, touch line, goal line, goal kick, off sides	Game play – Summative Example: Teacher observes for proper technique in game situations

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: 7**

	1 **2** **5**	**Ultimate Frisbee** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Frisbee, stall, end zone, touch down, sidelines, marking, count, pull	Group discussion- Formative Example: Fitness and sports are important to everyone's health. Is there away we can modify the game so we can include kids with disabilities? (Wheel chair, blind, deaf? – Students responses should come up with different modifications and how can do other games as well. Game play – Summative Example: Teacher observes for proper technique in game situations
Unit 3 **Striking implement games – cooperation, sportsmanship**	**2** **5**	**Sport 1: Table Tennis** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault	Group discussion- Formative Example: What is sportsmanship? How can we show good sportsmanship in games? – Students responses should talk about positive speak, following the rules, handshake.

TEACHER'S NAME: Stephanie Hartsoe **6/17**

			Game play – Summative Example: Teacher observes for proper technique in game situations
	1 2 5 6	**Sport 2: Tennis/Pickle ball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? • What makes physical activity meaningful? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault, foot fault	Group discussion – Formative Example: What does cooperation mean? We are playing games where you have a partner. How can we show good cooperation? Student responses should talk about listening to teammate, working together to win, sportsmanship. Game Play – Summative Example: Teacher observation for proper technique in serving the ball.
	2 5	**Badminton** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary**	Game play- Formative Example: Teacher observation looking for proper technique in forehand hit.

		Birdie, racquet, lob, drop, drive, swings: underhand, overhead, side arm	
Unit 4 **Aquatics**	**1** **2** **5**	**Basic Swim skills** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Lane rope, Starting blocks, dive, free style, butterfly, backstroke, breaststroke, float, treading water, life ring, life guard, first aid, flutter kick, dolphin dive	Swim each stroke – Summative Example: Teacher observe for proper technique in stroke.
Unit 5 **Fitness gram/ Physical Fitness**	**3** **4** **6**	**Personal Fitness Level - Post** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format - Summative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body

			off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position in a controlled manner. Allow two trials, record the highest score.

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE:** 8

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1 **Fitness gram/ Physical Fitness**	3 4 6	**Personal Fitness Level** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format - Formative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the

TEACHER'S NAME: Stephanie Hartsoe 6/17

			student returns to the starting position in a controlled manner. Allow two trials, record the highest score.
	3 **4** **6**	**FITT Principle** • What is the importance of being physically active? • Hoe does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Fitness components, cardiovascular endurance, muscular strength and muscular endurance, flexibility, body compositions, frequency, intensity, time and type.	F.I.T.T. Group discussion – Formative Example: Using your scores on the FitnessGram. Lets pick an area and go over some ways to help improve our score. Student's responses will put together workout plans. F.I.T.T. Student Plan – Summative Example: From discussion student will create a plan to improve one of their areas in the fitnessGram.
	2 **5**	**Track and Field** What are the concept, principles, strategies and tactics used in physical activity? What are the personal and social behavioral expectations in physical settings?	Group discussion - Formative Example: Which activities help with cardiovascular endurance? Which ones help with muscular strength?

		Content Specific Vocabulary Hurdles, dash, sprint, jump, distance, relays, shot put, long jump	Skill performance – Summative Example- Teacher observation for proper technique.
Unit 2 **Using Sports to stay active**	**1** **2** **5**	**Sport 1: Diamond Games: Softball, kickball, Baseball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Pitcher, catcher, baseman, short stop, outfielder, homerun, double play, strike zone, fair, foul, over throw, error, inning, walk	Group discussion – Formative Example: Softball is a game many say you can play young or old, why do you agree or disagree? Game play – Summative Example: Teacher observes for proper technique in game situations.
	2 **5**	**Sport 2: Floor Hockey** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Forward, defenseman, rover, goalie, puck, penalty, foul, rebound, hat trick, assist, goalie box	Group discussion – Formative Example: What are our expectations during this activity? Lets as a group think about the game and what are some of our personal expectations and some behavioral expectations while

	2 5	**Volleyball** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, bump, set, spike, ace, rotate, fault, underhand, overhead, assist, block, back row, carry, dig, double hit, foul, front row, lift, pass, rally scoring, side out	playing. Game play – Summative Example: Teacher observes for proper technique in game situations Group discussion -Formative Example: Being about to play an entire game of volleyball could be expected of you if you're on the volleyball team. You want to have more stamina to play longer. What are two activities you can do to help you? Explain how the activity is beneficial to your health.- Think about to other classes to help in the discussion. Game play – Summative Example: Teacher observes for proper technique in game situations

	1 2 5	**Basketball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, chest pass, bounce pass, lay up, double dribble, point guard, shooting guard, small forward, power forward, center, zone defense, man-to-man defense	Game play – Summative Example: Teacher observation for proper technique in dribbling skill.
	2 5	**Team handball** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Jump pass, overhand pass, wrist pass, catching, passive play, throw off, dribble	Group discussion – Formative Example: Team handball is a game that combines many other skills from other games. How does playing this game help improve ones overall fitness? Student's response should talk about muscular endurance and strength in different muscle groups. (Upper body and lower body.) Game play – Summative Example: Teacher observes for proper

			technique in game situations
	2 5	**Soccer** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, header, throw in, corner kick, striker, forward, defense, goalie, direct free kick, indirect free kick, touch line, goal line, goal kick, off sides	Game play – Summative Example: Teacher observes for proper technique in game situations
	1 2 5	**Ultimate Frisbee** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Frisbee, stall, end zone, touch down, sidelines, marking, count, pull	Group discussion- Formative Example: Fitness and sports are important to everyone's health. Is there away we can modify the game so we can include kids with disabilities? (Wheel chair, blind, deaf? – Students responses should come up with different modifications and how can do

			other games as well. Game play – Summative Example: Teacher observes for proper technique in game situations
Unit 3 **Striking implement games – cooperation, sportsmanship**	**2** **5**	**Sport 1: Table Tennis** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault	Group discussion- Formative Example: What is sportsmanship? How can we show good sportsmanship in games? – Students responses should talk about positive speak, following the rules, handshake. Game play – Summative Example: Teacher observes for proper technique in game situations
	1 **2** **5** **6**	**Sport 2: Tennis/Pickle ball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings?	Group discussion – Formative Example: What does cooperation mean? We are playing games where

	          2 5	• What makes physical activity meaningful? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault, foot fault **Badminton** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Birdie, racquet, lob, drop, drive, swings: underhand, overhead, side arm	you have a partner. How can we show good cooperation? Student responses should talk about listening to teammate, working together to win, sportsmanship. Game Play – Summative Example: Teacher observation for proper technique in serving the ball. Game play- Formative Example: Teacher observation looking for proper technique in forehand hit.
Unit 4 **Aquatics**	1 2 5	**Basic Swim skills** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Lane rope, Starting blocks, dive, free style, butterfly, backstroke, breaststroke, float, treading water, life ring, life guard, first aid, flutter kick, dolphin dive	Swim each stroke – Summative Example: Teacher observe for proper technique in stroke.

COURSE: Physical Education **GRADE: 8**

Unit 5 **Fitness gram/** **Physical** **Fitness**	**3** **4** **6**	**Personal Fitness Level - Post** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format – Summative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position

			in a controlled manner. Allow two trials, record the highest score.

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: 8**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1 **Fitness gram/ Physical Fitness**	3 4 6	**Personal Fitness Level** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format - Formative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the

			student returns to the starting position in a controlled manner. Allow two trials, record the highest score.
	3 4 6	**FITT Principle** • What is the importance of being physically active? • Hoe does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Fitness components, cardiovascular endurance, muscular strength and muscular endurance, flexibility, body compositions, frequency, intensity, time and type.	F.I.T.T. Group discussion – Formative Example: Using your scores on the FitnessGram. Lets pick an area and go over some ways to help improve our score. Student's responses will put together workout plans. F.I.T.T. Student Plan – Summative Example: From discussion student will create a plan to improve one of their areas in the fitnessGram.
	2 5	**Track and Field** What are the concept, principles, strategies and tactics used in physical activity? What are the personal and social behavioral expectations in physical settings?	Group discussion - Formative Example: Which activities help with cardiovascular endurance? Which ones help with muscular strength?

		Content Specific Vocabulary Hurdles, dash, sprint, jump, distance, relays, shot put, long jump	Skill performance – Summative Example- Teacher observation for proper technique.
Unit 2 **Using Sports to stay active**	**1** **2** **5**	**Sport 1: Diamond Games: Softball, kickball, Baseball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Pitcher, catcher, baseman, short stop, outfielder, homerun, double play, strike zone, fair, foul, over throw, error, inning, walk	Group discussion – Formative Example: Softball is a game many say you can play young or old, why do you agree or disagree? Game play – Summative Example: Teacher observes for proper technique in game situations.
	2 **5**	**Sport 2: Floor Hockey** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Forward, defenseman, rover, goalie, puck, penalty, foul, rebound, hat trick, assist, goalie box	Group discussion – Formative Example: What are our expectations during this activity? Lets as a group think about the game and what are some of our personal expectations and some behavioral expectations while

	2 5	**Volleyball** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, bump, set, spike, ace, rotate, fault, underhand, overhead, assist, block, back row, carry, dig, double hit, foul, front row, lift, pass, rally scoring, side out	playing. . Game play – Summative Example: Teacher observes for proper technique in game situations Group discussion -Formative Example: Being about to play an entire game of volleyball could be expected of you if you're on the volleyball team. You want to have more stamina to play longer. What are two activities you can do to help you? Explain how the activity is beneficial to your health.- Think about to other classes to help in the discussion. Game play – Summative Example: Teacher observes for proper technique in game situations

	1 2 5	**Basketball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, chest pass, bounce pass, lay up, double dribble, point guard, shooting guard, small forward, power forward, center, zone defense, man-to-man defense	Game play – Summative Example: Teacher observation for proper technique in dribbling skill.
	2 5	**Team handball** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Jump pass, overhand pass, wrist pass, catching, passive play, throw off, dribble	Group discussion – Formative Example: Team handball is a game that combines many other skills from other games. How does playing this game help improve ones overall fitness? Student's response should talk about muscular endurance and strength in different muscle groups. (Upper body and lower body.) Game play – Summative Example: Teacher observes for proper

			technique in game situations
	2 5	**Soccer** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, header, throw in, corner kick, striker, forward, defense, goalie, direct free kick, indirect free kick, touch line, goal line, goal kick, off sides	Game play – Summative Example: Teacher observes for proper technique in game situations
	1 2 5	**Ultimate Frisbee** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Frisbee, stall, end zone, touch down, sidelines, marking, count, pull	Group discussion- Formative Example: Fitness and sports are important to everyone's health. Is there away we can modify the game so we can include kids with disabilities? (Wheel chair, blind, deaf? – Students responses should come up with different modifications and how can do

			other games as well. Game play – Summative Example: Teacher observes for proper technique in game situations
Unit 3 **Striking implement games – cooperation, sportsmanship**	**2** **5** **1** **2** **5** **6**	**Sport 1: Table Tennis** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault **Sport 2: Tennis/Pickle ball** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings?	Group discussion- Formative Example: What is sportsmanship? How can we show good sportsmanship in games? – Students responses should talk about positive speak, following the rules, handshake. Game play – Summative Example: Teacher observes for proper technique in game situations Group discussion – Formative Example: What does cooperation mean? We are playing games where

		• What makes physical activity meaningful? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault, foot fault	you have a partner. How can we show good cooperation? Student responses should talk about listening to teammate, working together to win, sportsmanship. Game Play – Summative Example: Teacher observation for proper technique in serving the ball.
	2 5	**Badminton** • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Birdie, racquet, lob, drop, drive, swings: underhand, overhead, side arm	Game play- Formative Example: Teacher observation looking for proper technique in forehand hit.
Unit 4 Aquatics	1 2 5	**Basic Swim skills** • What ways can I use physical activities throughout my life? • What are the concept, principles, strategies and tactics used in physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Lane rope, Starting blocks, dive, free style, butterfly, backstroke, breaststroke, float, treading water, life ring, life guard, first aid, flutter kick, dolphin dive	Swim each stroke – Summative Example: Teacher observe for proper technique in stroke.

COURSE: Physical Education **GRADE: 8**

Unit 5 **Fitness gram/** **Physical** **Fitness**	**3** **4** **6**	**Personal Fitness Level - Post** • What is the importance of being physically active? • How does my health benefit from being physically fit? • What makes physical activity meaningful? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format – Summative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position

			in a controlled manner. Allow two trials, record the highest score.

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: High School**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1 **Fitness Gram**	**3** **4** **6**	**Personal Fitness Level – Pre Test FitnessGram** • What is the importance of being physically active? • How can I include physical fitness into my life? • What personal meaning do I find through participation in physical activity? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format – Formative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: High School**

			in a controlled manner. Allow two trials, record the highest score.
Unit 2 **Teamwork and Sportsmanship** **Team Sports**	2 5 6	**Volleyball** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What makes physical activity meaningful? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, bump, set, spike, ace, rotate, fault, underhand, overhead, assist, block, back row, carry, dig, double hit, foul, front row, lift, pass, rally scoring, side out	Game Play- Formative Example: Teacher observes proper technique Volleyball quiz- Summative Example: In volleyball you must play with teammates to win the game.(not an individual sport) What are ways to keep moral up during a game?
	2 5 6	**Basketball** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? • What personal meaning do I find through participation in physical activity? **Content Specific Vocabulary** Dribble, chest pass, bounce pass, lay up, double dribble, point guard, shooting guard, small forward, power forward, center, zone defense, man-to-man defense	Game Play- Formative Example: Teacher observes proper technique Basketball quiz- Formative Example: In basketball there are different points awarded for different shots. Explain how many points can be earned and how they are earned.
	2		

COURSE: Physical Education **GRADE: High School**

	5 6	**Flag Football** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? • What personal meaning do I find through participation in physical activity? **Content Specific Vocabulary** Flag, touchdown, end zones, field goal, quarterback, blocking, defense, yards, points, linebacker, referee, clipping, holding,	Game Play- Formative Example: Teacher observes proper techique Flag Football quiz- Summative Example: How can negative/positive sportsmanship affect team mates, coaches, referees and the score of a game?
Unit 3 Inclusion through team sports	1 2 5	**Team handball** • How do I make motor skills and physical activity an integral part of my life? • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Jump pass, overhand pass, wrist pass, catching, passive play, throw off, dribble	Game Play- Formative Example: Teacher observes proper technique Team handball quiz- Summative Example: Once you get the ball, you may take three running steps before releasing it to dribble or before passing it off. Did we make any changes in this rule to help include anyone with disabilities, if so what was the modification and who for?

	1 **2** **5**	**STXBALL** • How do I make motor skills and physical activity an integral part of my life? • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Attack, midfield, defense, goalie, crease, Crosse, face off, cradle, ground ball, scoop	Game Play- Formative Example: Teacher observes proper technique STXball quiz - Summative Example: How did we modify the rules in the game to include more active participation?
	1 **2** **4** **5**	**Soccer** • How do I make motor skills and physical activity an integral part of my life? • What concepts, principles, strategies and tactics do apply to specific physical activity? • How can I include physical fitness into my life? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Dribble, header, throw in, corner kick, striker, forward, defense, goalie, direct free kick, indirect free kick, touch line, goal line, goal kick, off sides	Game Play – Formative Example: Teacher observes proper technique Soccer quiz – Summative Example: How can we incorporate a child who has a wheel chair into the game? Fitness Gram: administered twice a year in a pre-test and post-test format –
Unit 4 **Fitness Gram**	**3** **4**	**Personal Fitness Level – Post Test FitnessGram** • What is the importance of being physically active?	Summative

	6	• How can I include physical fitness into my life? • What personal meaning do I find through participation in physical activity? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position in a controlled manner. Allow two trials, record the highest score.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: High School PE 1**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1 Fitness Gram	3 4 6	**Personal Fitness Level – Pre-Test FitnessGram** • What is the importance of being physically active? • How can I include physical fitness into my life? • What personal meaning do I find through participation in physical activity? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Fitness Gram: administered twice a year in a pre-test and post-test format - Formative Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position in a controlled manner. Allow two trials,

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CURRICULUM FRAMEWORK

COURSE: Physical Education **GRADE: High School PE 1**

			record the highest score.
Unit 2 **Fit for Life**	1 3 4	**Fit For Life – Fit improvement plan** • How do I make motor skills and physical activity an integral part of my life? • What can I do to be physically active throughout my life? • How can I include physical fitness into my life? **Content Specific Vocabulary** F.I.T.T, Frequency, Intensity, Time, Type, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Journals – Formative Fitness Plan – Formative Journal Example: Explain to your character what you have noticed about their current health status using the fitness gram results to prove your point. Explain to your character what you think they should be working on to improve their health and why they should be doing it.
Unit 3 **Weight Training/ Conditioning**	2 3 4	**Intro to weight training/conditioning** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What can I do to be physically active throughout my life? • How can I include physical fitness into my life? **Content Specific Vocabulary** Obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance circuit, anaerobic, aerobic, endurance, agility, toning, repetitions, set, full range of motion, clamps, core exercises, isolate, max, spotters, muscles (biceps, quadriceps)	Work-out logs Technique checklist – Formative Example- Teacher looking for proper technique Weight training quiz – Summative Running long distance, swimming non-stop for 30 minutes, and using an elliptical machine for 20 minutes are all examples of: 1. anaerobic exercise 2. power exercise 3. aerobic exercise

			4. strength training
Unit 4 **Using Sports to Stay Active**	2 4 5 2 5	**Sport 1: Diamond Games: Softball, kickball, Baseball** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? • How can I include physical fitness into my life? **Content Specific Vocabulary** Pitcher, catcher, baseman, short stop, outfielder, homerun, double play, strike zone, fair, foul, over throw, error, inning, walk **Sport 2: Floor Hockey** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Forward, defenseman, rover, goalie, puck, penalty, foul, rebound, hat trick, assist, goalie box	Game Play- Formative Example: Teacher observes for proper technique Softball quiz – Summative Example: What are benefits of playing softball in an adult league Game Play- Formative Example – Teacher observes for proper technique Floor Hockey quiz – Summative Drawing from previous units, how can playing on an indoor floor hockey team be beneficial in later years?

	2 5	**Sport 3: Table Tennis** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault	Game Play – Summative Example: Teacher observes for proper technique
	2 5	**Sport 4: Tennis/Pickle ball** • What concepts, principles, strategies and tactics do apply to specific physical activity? • What is the importance of being physically active? • What concepts, principles, strategies and tactics do apply to specific physical activity? • What are the personal and social behavioral expectations in physical settings? **Content Specific Vocabulary** Serve, volley, single, doubles, toss, let, racquet, net, ball, crosscourt, forehand, backhand, ace, alley, set, fault, foot fault	Game Play- Formative Example: Teachers observes for proper technique Tennis/Pickle ball quiz - Summative Example: How does your health benefit from weekly games of tennis?
Unit 6 Fitness Gram	3 4 6	**Personal Fitness Level – Post-Test FitnessGram** • What is the importance of being physically active? • How can I include physical fitness into my life?	Fitness Gram: administered twice a year in a pre-test and post-test format - Summative

		• What personal meaning do I find through participation in physical activity? **Content Specific Vocabulary** Pacer, curl up, trunk lift, push ups, flexed arm hang, back-saver sit-n-reach, shoulder stretch, height, weight, obesity, muscular strength, cardiovascular endurance, flexibility, muscular endurance	Example: Trunk lift- lifts the upper body off the floor using the muscles of the back and hold the position to allow for the measurement. Student lies on the mat in a prone position (Facedown) Toes are pointed and hands are placed under the thighs. A coin is placed on the floor in line with the student's eyes. Student must focus on coin during the movement. Student lifts the upper body off the floor, in a very slow and controlled manner, to the maximum score of 12 inches. The head should be maintained in a neutral alignment with the spine. The position is held long enough to allow the tester to place the ruler on the floor in front of the student and determine the distance from the floor to the student's chin. Once the measurement has been made, the student returns to the starting position in a controlled manner. Allow two trials, record the highest score.

Unit	Standards	Unit Concept/Essential Questions	Assessments
Module 1	**Scientific Inquiry Standard Area: Perspectives in Psychological Science** Standards: 1 & 2	**History and Perspectives in Psychological science** • What is psychology? • Is psychology a science? • What psychologists are famous in the field? • What are the 6 Perspectives and why are they important to the practice of psychology? **Content Specific Vocabulary** psychology, perspectives, Wundt, Titchner, James, Freud, Pavlov, Watson, Skinner, Maslow, Rogers, Piaget, Clark	Formative Mod. Assessment Summative Research: Bio of Psychologist
Module 2	**Scientific Inquiry Standard Area: Research Methods, Measurement, and Statistics** Standards: 1 & 2	**Research Strategies** • How do we do research in psychology? • Define term for research: hypothesis. • What is the purpose of an Institutional Review Board? **Content Specific Vocabulary** research, scientific method, bias, observation, experiment, variable	Formative: Mod. Assessment Summative: Research/IRB: Using Electronic Devices and the Effect on Academic Grades
Module 3	**Scientific Inquiry Standard Area: Research Methods, Measurement, and Statistics** Standard: 3	**Psychology and Statistics** • Describing data and statistics. How do we use statistics in psychological research? • Define terms: mean, mode, median, frequency, range **Content Specific Vocabulary** skewed, normal distribution, correlation, inferential statistics, significance	Formative: Mod. Assessment Summative: Describing data with statistical analysis
Module 4	**Biopsychology Standard Area: Biological Basis of Behavior** Standards: 1 & 2	**Nervous/Endocrine Systems** • Define "neuron". • How do neurons communicate? • How are neurons/endocrine systems structured? **Content Specific Vocabulary** synapse, antagonist, central nervous system, hormone	Formative: Mod. Assessment Summative Career Research: what dc specialized psychologists do?
Module 5	**Biopsychology Standard Area: Biological Basis**	**The Brain** • How is the brain structured? • What is the Limbic system?	Formative Mod Assessment Summative

	of Behavior Standards: 3 & 4	• What does it do? **Content Specific Vocabulary** PET scan, Medulla, thalamus, MRI, hippocampus, amygdala, frontal lobe, Broca's Area, Wernicke's area	
Module 6	**Biopsychology Standard Area: Sensation and Perception** Standards: 1 & 2	**Sensation** • Define "sensation". • From where does the nervous system receive stimuli? • How does sensation contribute to behavior? **Content Specific Vocabulary** bottom-up processing, top-down processing, threshold	Formative:Mod Assessment Summative:
Module 7	**Biopsychology Standard Area: Sensation and Perception** Standard: 3	**Perception** • Define Perception. • What is the process for organizing and interpreting sensory information? **Content Specific Vocabulary** gestalt, convergence, ESP, grouping, depth perception	Formative: Mod Assessment Summative:
Module 8	**Biopsychology Standard Area: States of Consciousness** Standards: 1 & 2	**Sleep, Dreams, Body Rhythms** • What happens to our brain while we sleep? • What is consciousness? **Content Specific Vocabulary** biological rhythms, melatonin, EEG, REM, sleep disturbances	Formative: Mod Assessment
Module 9	**Biopsychology Standard Area: States of Consciousness** Standard: 3	**Psychoactive Drugs** • What are psychoactive drugs? • How do they affect our brains? • How do these drugs alter our perception, mood and behavior? **Content Specific Vocabulary** dependence, depressants, stimulants, amphetamines, hallucinogens, marijuana	Formative Mod Assessment Summative: Research assignment: Investigating specific legal and illegal drugs and their effects.
Module10	**Biopsychology Standard Area: States of Consciousness** Standard: 4	**Hypnosis and Other States of Consciousness** • What is "hypnosis"? • Are we conscious or unconscious while under hypnosis? **Content Specific Vocabulary** consciousness, social influence theory, Hilgard	Formative: Mod Assessment Summative:
Module 11	**Development &**	**Pre-Natal/Childhood**	Formative: Mod Assessment

	Learning **Standard Area: Life-Span Development** Standards: 1,2,3,4,5	• What are the first 3 stages of human development? • When do they occur? • What psychologists are involved in this area of human development research? • How are their theories the same? Different? **Content Specific Vocabulary** zygote, genes, embryo, fetus, FAS, developmental psychology, authoritarian, permissive, authoritative. Piaget, Lorenz	Summative
Module12	**Development & Learning** **Standard Area: Life-Span Development** Standards: 1,2,6	**Adolescence** • Define "adolescence". • What are the characteristics of adolescence? • What constitutes the transition from childhood to adolescence? • From adolescence to adulthood? **Content Specific Vocabulary** puberty, identity, intimacy, Kohlberg, Erickson	Formative: Mod Assessment
Module 13	**Development & Learning** **Standard Area: Life-Span Development** Standard: 7	**Adulthood & Aging** • Define "emerging adulthood". • What kinds of transitions occur during adulthood? **Content Specific Vocabulary** menopause, Alzheimer's disease, senile dementia, fluid intelligence, crystallized intelligence	Formative: Mod Assessment Summative:Research essay: What are your values and life goals?
Module 14	**Development & Learning** **Standard Area: Learning** Standard: 1	**Classical Conditioning** • What are the components of Classical conditioning? • Who are the psychologists who have contributed to this theory of learning? • How are their theories the same? Different? **Content Specific Vocabulary** learning, stimulus, response, acquisition, extinction, behaviorism, cognition, Pavlov, Watson, Rescorla	Formative: Mod Assessment Summative:
Module 15	**Development & Learning** **Standard Area: Learning** Standard: 2	**Operant Conditioning** • Define "operant conditioning". • Who were the psychologists who espoused this theory of learning? **Content Specific Vocabulary** reinforcement, punishment, interval schedule, latent learning, Thomdike, Skinner	Formative: Mod Assessment Summative: Research: interview/observation of child and interview of adult. Written reports of findings.

Module 16	**Development & Learning Standard Area: Learning** Standard: 3	**Observational Learning** • Define "observational learning". • Who were the psychologists who espoused this theory of learning? • How did they differ? Agree? **Content Specific Vocabulary** model, vicarious learning, mirror neurons, anti-social behavior, pro-social behavior, Bandura	Formative: Mod Assessment Summative: Mid-year exam
Module 17	**Development & Learning Standard Area: Language Development** Standards: 1 & 2	**Language Development** • Who were the primary psychologists with theories about how children develop language? • How did they differ in their ideas? • What were the components of the primary theories? **Content Specific Vocabulary** : language, phoneme, morpheme, grammar, Chomsky, Skinner	Formative Mod Assessment Summative: Compare/contrast essay on language theorists
Module 18	**Socio-Cultural Standard Area: Social Interactions** Standards: 1 & 3	**Social Thinking & Social Influence** • How much of human behavior is a result of social thinking? • How much a result of peer/ environmental influence? • Define "ethics" and "integrity". • What is the Belmont Report and why is it important to psychology and psychological research? **Content Specific Vocabulary** attribution theory, self-serving bias, conformity, groupthink, Zimbardo, Asch, Milgram	Formative: Mod Assessment Summative: Research: Belmont Repo written essay on findings
Module 19	**Socio-Cultural Standard Area: Social Interactions** Standard: 3	**Social Relations** • What factors contribute to our attraction to others? • How do humans develop relationships? • What is discrimination and how does it affect relationships? **Content Specific Vocabulary** equity, altruism, prejudice, stereotype, discrimination, scapegoat theory, other-race effect, aggression, Darley, Latane'	Formative: Mod Assessment Summative: Response to Scenarios: "Institutional Discrimination"
Module 20	**Socio-Cultural Standard Area: Social Interactions** Standards: 1 & 3	**Nature vs. Nurture** • Define nature. Nurture. • How are they different? • What factors contribute to the nature-nurture debate? • How has psychological evolution change learning for different cultures?	Formative: Mod Assessment Summative: Research: Evolutionary Psychology and Intercultural Learning

		Content Specific Vocabulary behavior genetics, genes, environment, DNA, mutation, heritability, culture, norms	
Module 21	**Socio-Cultural Standard Area: Social Interactions** Standard: 1	**Psychology of Culture and Gender** • What defines "culture"? • What defines "gender"? • How do our culture and gender impact our behavior? **Content Specific Vocabulary** culture, individualism, culture specific, locus of control, ethnocentrism, gender, gender identity, Matsumoto	Formative: Mod Assessment Summative: Behavior: Evolutionary Psychology: How has human behavio changed over time?
Module 22	**Cognition Standard Area: Information Processing** Standards: 1,2,3	**Information Processing** • How does our memory work? • What is the process for remembering? • What contributes to our ability to remember things over a long time period? **Content Specific Vocabulary** encoding, storage, retrieval, rehearsal, mnemonic, chunking, flashbulb memory, recognition, explicit/implicit memory, Ebbinghaus	Formative: Mod assessment Summative:
Module 23	**Cognition Standard Area: Information Processing** Standard: 3	**Forgetting and Memory Construction** • Why do we forget? • What kinds of things do we forget? • What kinds of memories do we form? • How do we construct new memories? **Content Specific Vocabulary** retroactive interference, repression, misinformation effect, Loftus	Formative: Mod Assessment Summative:
Module 24	**Cognition Standard Area: Thinking** Standards: 1 & 2	**Thinking** • What concepts do we use for problem solving? • What problems do encounter trying to solve problems? **Content Specific Vocabulary** cognitive abilities, concept, prototype, algorithm, heuristic, functional fixedness, confirmation bias, framing, Kahneman	Formative: Mod Assessment Summative: Behavior Research: Problem Solving Strategies
Module 25	**Cognition Standard Area: Intelligence**	**Intelligence and Intelligence Testing** • What is intelligence? • Who are some of the psychologists involved in defining intelligence?	Formative: Mod Assessment Summative: Research: IQ and IQ testing: equality in tests

	Standards: 1,2,3	• What kinds of tests are considered Intelligence Quotient (IQ) tests? • Who are some of the leaders in creating IQ tests? • What is the difference among IQ, Achievement, and Aptitude tests? • Different kinds of "intelligence". **Content Specific Vocabulary** emotional intelligence, mental age, IQ, reliability, validity, Gardner, Stemberg, Binet, Terman, Weschler	
Module 26	**Individual Variations Standards Area: Motivation** Standards: 1 & 2	**Motivation and Emotion** • What is "Motivation"? • Define "instinct"? How is it different from motivation? • What are the biological theories of motivation? • What are the cognitive and clinical explanations of motivation? **Content Specific Vocabulary** Yerkes-Dodson Law, homeostasis, extrinsic motivation, intrinsic motivation, hierarchy of needs, Maslow, Murray	Formative: Mod Assessment Summative: Assessments: Extrinsic/Intrinsic Motivation and revie Research: Savant Syndrome
Module 27	**Individual Variations Standards Area: Emotion** Standards: 1,2,3	**Emotion** • What is "emotion"? • Who are some of the psychologists who studied human emotion? • How is human nervous system related to emotion? • What ways do humans express emotion? **Content Specific Vocabulary** James-Lang Theory, Cannon-Bard Theory, autonomic nervous system	Formative: Mod Assessment Summative: Motivation Essay: Intrinsi and extrinsic motivation to improve academic grades.
Module 28	**Individual Variations Standards Area: Personality** Standards: 1 & 2	**Psychodynamic and Humanistic Perspectives on Personality** • What contribution did Freud make to Psychodynamic psychology? • What kinds of assessments are used in this area of psychology? • How is Humanism different from Freudian psychology? • Who are other psychologists who fall into this realm? **Content Specific Vocabulary** : personality, psychosis, TAT, Rorschach Inkblot, humanistic psychology, self-concept	Formative: Mod Assessment Summative: Personality assessments completion and review
Module 29	**Individual Variations Standards Area:**	**Trait and Social-Cognitive Perspectives on Personality** • What are some different personality types? • What psychologists are associated with this area of psychology?	Formative: Mod Assessment Summative: PSAT Research

	Personality Standards 1 & 2	**Content Specific Vocabulary** traits, MMPI, positive psychology, personality inventories	
Module 30	**Individual Variations** **Standards Area: Psychological Disorders** Standards: 1 & 2	**Introduction to Psychological Disorders** • What is "abnormal"? • Are disorders different in others cultures? • What is the DSM? • What are the 6 Core Dimensions defining mental health? • What are some misconceptions of mental health disorders? • What effect can "labeling" have? **Content Specific Vocabulary** psychological disorder, medical model, bio-psycho-social model, Pinel	Formative: Mod Assessment Summative: Sternberg Research: Writing a Test according to Sternberg' Emotional Intelligence
Module 31	**Individual Variations** **Standards Area: Psychological Disorders** Standards: 1 & 2	**Anxiety and Mood Disorders** • What are some of the causes of anxiety disorders? • What causes Mood disorders? • List some specific disorders: anxiety and mood. **Content Specific Vocabulary** anxiety, panic disorder, phobia, OCD, PTSD, bipolar disorder	Formative: Mod Assessment Summative: Anxiety and Mood Disorders Research/essay
Module 32	**Individual Variations** **Standards Area: Psychological Disorders** Standard: 2	**Dissociative, Schizophrenic Personality Disorders** • Define "Dissociative". • What are some of the disorders in the category of Dissociative? • What are the varied characteristics of Schizophrenia? • What characterizes a "personality" disorder? **Content Specific Vocabulary** amnesia, fugue, somatoform, hypocondriasis, antisocial personality disorder	Formative: Mod Assessment Summative:
Module 33	**Applications of Psychological Science** **Standards Area: Treatment of Psychological Disorders** Standards: 1,2,3	**Psychological Therapies** • Compare/contrast the 4 Therapies: Psychoanalysis, Humanistic, Behavior, Cognitive. • What are some compulsive behaviors? • What are some "Real World" issues with psychology? **Content Specific Vocabulary** resistance, interpretation, transference, client-centered therapy, token economy, cognitive therapy, aversive conditioning	Formative: Mod. Assessment Summative:

Module 34	**Applications of Psychological Science Standards Area: Treatment of Psychological Disorders** Standards: 1,2,3	**Biomedical Therapies** • Define "biomedical" therapies. • How have biomedical therapies evolved over the last 2 centuries? • Specifically, what is the danger of lobotomies? • Who were the doctors involved in the first hospital lobotomies? **Content Specific Vocabulary** antipsychotic drugs, ECT, antidepressant drugs, institutionalization	Formative: Mod Assessment Summative:
Module 35	**Applications of Psychological Science Standards Area: Stress, Coping and Health** Standard: 1	**Effects of Stress** • How is "stress" defined by psychologists? • What is "Health Psychology"? • What are some of the theories behind avoiding stress and remaining healthy mentally? **Content Specific Vocabulary** general adaptation syndrome, type A, type B, Cannon, Selye	Formative: Mod Assessment Summative:
Module 36	**Applications of Psychological Science Standards Area: Stress, Coping and Health** Standard: 2	**Promoting Wellness** • How is "optimism" related to good mental health? • What are the 10 contributors to a healthy lifestyle? **Content Specific Vocabulary** wellness, BMI, set point, Seligman	Formative: Mod Assessment Summative: Optimism evaluation: completion and review

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Music **GRADE: 6**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Star-Spangled Banner	MU:Pr4.1.6 MU:Pr4.2.6 MU:Pr4.3.6 MU:Pr5.1.6 MU:Pr6.1.6 MU: Re7.1.6 MU: Re7.2.6 MU: Re8.1.6 MU: Re9.1.6	History / Background – Star-Spangled DVD • What is an anthem? • Why did F. S. Key write his poem? • How was the music chosen? Why? Performance comparison / critiques and etiquette – Jimi Hendrix, Whitney Houston, Renee Fleming • Where would the national anthem be performed? • Who performed it better? What other songs would be a good choice for the national anthem? • Is "The Star-Spangled Banner" your choice for a national anthem? Reading and singing the music • Why is music notation important? • How do performers interpret musical works? • Why is practice important? Content Specific Vocabulary Anthem, music, lyrics, time signature, meter, stanza, tempo, pitch, range, expression, style, dynamics	In class discussion – Formative Class performance – Formative Opinion paragraph – Summative Quiz – Summative Formative sample discussion Why do some think that the Star-Spangled Banner is hard to sing? Summative sample quiz question Define "anthem". Sample performance task Sing the Star-Spangled Banner demonstrating concepts of pitch and expression. (Instructor-designed rubric.)

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2 – Intro to Acting	TH:Cr1.1.6 TH:Cr2.1.6 TH:Cr3.1.6 TH:Pr4.1.6 TH:Pr5.1.6.	SHREK: THE MUSICAL • Why use fairy tale characters? • How is a movie different from a live performance? Behind the scenes • Why is a director important? • Who are the people who make up the crew? Staging a performance • What do you consider when blocking a scene? • What are the quadrants of a stage? Analyze the performance • What makes a performance interesting? Content Specific Vocabulary Musical, drama, comedy, character, blocking, super objective, objective, goal, beat, intent, staging, character traits	In class viewing and discussion – Formative Create a poster – Summative Formative sample discussion How do the songs in SHREK advance the plot? Summative poster prompt Design a poster that illustrates one or more IB learner profile attributes that are found in SHREK. (Graded by instructor-designed rubric.) Performance task Perform a scene from SHREK. (Instructor-designed rubric.)
3 – Notation and Composition	MU:Cr1.1.6 MU:Cr2.1.6 MU:Cr3.1.6 MU:Cr3.2.6	The staff • Why is music an international language? Notes and rests • Are sound and silence equally important in music? Intervals • What is an interval?	In class demonstration and interactive composing and arranging - Formative Notation worksheets – Summative Formative sample: Name that chord / interval game.

		Major and minor modes • What makes a piece sound "happy"? "Sad"? Compose and arrange a song • How do you get started when composing a piece? Content Specific Vocabulary Staff, note and rest values, style, tempo, mood, range, pitch, intervals, major, minor, mode, chord, harmonic, melodic, clef	Summative sample Notate two different G's on the treble staff.
4 – Music History	MU: Re7.2.6 MU: Re9.1.6 MU: Cn11.1.6	The Baroque Era • What are characteristics of baroque music? Vivaldi, Bach, and Handel • Who are the chief composers of the baroque era? Handel's MESSIAH • What is an oratorio? • What is ABA form? Content Specific Vocabulary Baroque, oratorio, opera, soprano, alto, tenor, bass, form, ornamentation	In class composer study and worksheet – Formative Quiz – Summative Formative sample question Handel composed vocal music with texts in a. Italian b. German c. English d. all of the above

			Summative sample question What are the four vocal parts in Handel's MESSIAH?

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Performing Arts **GRADE 6**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Star-Spangled Banner	MU:Pr4.1.6 MU:Pr4.2.6 MU:Pr4.3.6 MU:Pr5.1.6 MU:Pr6.1.6 MU: Re7.1.6 MU: Re7.2.6 MU: Re8.1.6 MU: Re9.1.6	**History / Background – Star-Spangled DVD** • What is an anthem? • Why did F. S. Key write his poem? • How was the music chosen? Why? **Performance comparison / critiques and etiquette – Jimi Hendrix, Whitney Houston, Renee Fleming** • Where would the national anthem be performed? • Who performed it better? **What other songs would be a good choice for the national anthem?** • Is "The Star-Spangled Banner" your choice for a national anthem? **Reading and singing the music** • Why is music notation important? • How do performers interpret musical works? • Why is practice important? **Content Specific Vocabulary** Anthem, music, lyrics, time signature, meter, stanza, tempo, pitch, range, expression, style, dynamics	In class discussion – Formative Class performance – Formative Opinion paragraph – Summative Quiz – Summative Formative sample discussion: Why do some think that the Star-Spangled Banner is hard to sing? Summative sample quiz question: Define "anthem". Performance task: Sing the Star-Spangled Banner demonstrating concepts of pitch and expression. (Instructor-designed rubric.)
2 – Intro to	TH:Cr1.1.6	**SHREK: THE MUSICAL**	In class viewing and discussion –

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Acting	TH:Cr2.1.6 TH:Cr3.1.6 TH:Pr4.1.6 TH:Pr5.1.6.	• Why use fairy tale characters? • How is a movie different from a live performance? **Behind the scenes** • Why is a director important? • Who are the people who make up the crew? **Staging a performance** • What do you consider when blocking a scene? • What are the quadrants of a stage? **Analyze the performance** • What makes a performance interesting? **Content Specific Vocabulary** Musical, drama, comedy, character, blocking, super objective, objective, goal, beat, intent, staging, character traits	Formative Create a poster – Summative Formative sample discussion: How do the songs in SHREK advance the plot? Summative poster prompt: Design a poster that illustrates one or more IB learner profile attributes that are found in SHREK. (Graded by instructor-designed rubric.) Performance task: Perform a scene from SHREK. (Instructor-designed rubric.)
3 – Notation and Composition	MU:Cr1.1.6 MU:Cr2.1.6 MU:Cr3.1.6 MU:Cr3.2.6	**The staff** • Why is music an international language? **Notes and rests** • Are sound and silence equally important in music?	In class demonstration and interactive composing and arranging - Formative Notation worksheets – Summative

		Intervals • What is an interval? **Major and minor modes** • What makes a piece sound "happy"? "Sad"? **Compose and arrange a song** • How do you get started when composing a piece? **Content Specific Vocabulary** Staff, note and rest values, style, tempo, mood, range, pitch, intervals, major, minor, mode, chord, harmonic, melodic, clef	Formative sample: Name that chord / interval game. Summative sample: Notate two different G's on the treble staff.
4 – Music History	MU: Re7.2.6 MU: Re9.1.6 MU: Cn11.1.6	**The Baroque Era** • What are characteristics of baroque music? **Vivaldi, Bach, and Handel** • Who are the chief composers of the baroque era? **Handel's MESSIAH** • What is an oratorio? • What is ABA form? **Content Specific Vocabulary** Baroque, oratorio, opera, soprano, alto, tenor, bass, form, ornamentation	In class composer study and worksheet – Formative Quiz – Summative Formative sample question: Handel composed vocal music with texts in a. Italian b. German c. English d. all of the above Summative sample question:

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CURRICULUM FRAMEWORK

COURSE: Performing Arts **GRADE 6**

			What are the four vocal parts in Handel's MESSIAH?

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CURRICULUM FRAMEWORK

COURSE: Music **GRADE: 7**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Music History	MU: Re7.2.7 MU: Re9.1.7 MU: Cn11.1.7 MU:Pr4.2.7	**The Classical Era** • What are characteristics of classical music? **Haydn, Mozart, Beethoven** • Who are the chief composers of the classical era? **Musical Forms** • What is a sonata? • What is a concerto? **Content Specific Vocabulary** Classical, minuet, trio, rondo, sonata, concerto, theme and variations, structure, symphony, string quartet	In class composer study and worksheet – Formative Quiz – Summative Formative sample question Mozart composed_______________. a. operas b. symphonies c. oratorios d. all of the above Summative sample question: Why is Beethoven considered a "bridge" composer?
2 – Mozart and his music	MU:Pr4.2.7 MU:Pr6.1.7 MU:Re7.1.7 MU:Re7.2.7 MU:Re8.1.7 MU:Re9.1.7 MU:Cn10.1.7 MU:Cn11.1.7	**AMADEUS movie** • What is the literary inspiration for the movie AMADEUS? • Why are some movies considered more artistic than others? **Behind the scenes** • Why is a scenic designer important? • Who are the people who make up the crew?	In class viewing and discussion – Formative Movie worksheet and note-taking – Formative Create a poster – Summative

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		Creating a character • How can makeup help in the creation of a character? **Analyze the performance** • What makes a performance interesting? **Musical forms** • What kinds of pieces did Mozart compose? **Historic and Cultural Tie-ins** • Who was alive at the same time as Mozart? • Why did Mozart use Italian and German librettos for his operas? • Is Mozart's music still alive today? • Is musical longevity a sign of "good" music? **Content Specific Vocabulary** Prodigy, Vienna, Austria, opera, singspiel, concerto, emperor, arch-bishop, theatre, comedy, tragedy, libretto, conflict, resolution	Formative sample discussion Describe the differences between Mozart's and Salieri's compositional techniques. Sample worksheet question What is a requiem? Summative poster prompt Design a poster that illustrates one or more IB learner profile attributes that are found in AMADEUS. (Graded by instructor-designed rubric.)
3 – THE MAGIC FLUTE	TH:Cr.1.1.7 TH:Cr2.1.7 TH:Cr3.1.7 TH:Pr4.1.7 TH:Pr6.1.7 TH:Re8.1.7 TH:Re9.1.7 TH:Cn10.1.7	**Intro to opera** • What is opera? **Themes** • What are the major themes in THE MAGIC FLUTE? **Voices and Orchestration** • What thought goes into selecting different voices and / or instruments when composing a	In class viewing, note-taking, and discussion - Formative Quiz – Summative Formative sample discussion Who is the only character in THE MAGIC FLUTE to introduce himself by

	TH:Cn11.1.7 TH:Cn11.2.7	piece? **Content Specific Vocabulary** Opera, singspiel, soprano, alto, tenor, bass, coloratura, opera seria, opera buffa,	name? Why is this important? Summative sample question "Hmm, hmm, hmm…" is an example of: a. a trio b. a duet c. a quintet Performance task: Collaborating with a group – write, stage, and perform a scene from THE MAGIC FLUTE. (Instructor-designed rubric.)
4 – SMOKEY JOE'S CAFE	TH:Re7.1.7 TH:Re8.1.7 TH:Re9.1.7 TH:Cn11.2.7	**Review vs. revue** • What is a review? • What is a revue? **Rock and roll in the 1950's and 1960's** • Why were there so few African-American artists? • How did artists from the 1950's influence today's artists? **Compare and Contrast** • Who originally recorded "Hound Dog"? **Writing a review** • How do you write a review?	In class viewing, note-taking, and discussion – Formative Write a one page review of SMOKEY JOE'S CAFÉ – Summative (Instructor-designed rubric.)

		Content Specific Vocabulary Review, revue, Broadway, choreography, rock and roll, Jerry Leiber, Mike Stoller, interpretation, audience etiquette	

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CURRICULUM FRAMEWORK

COURSE: Music **GRADE: 8**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Music History	MU: Re7.2.8 MU: Re9.1.8 MU: Cn11.1.8 MU:Pr4.2.8	**The Romantic Era** • What are characteristics of romantic music? **Mendelssohn, Brahms, Chopin, Tchaikovsky** • Who are the chief composers of the romantic era? **Musical Forms** • What is a string quartet? • What is an opera? **Content Specific Vocabulary** Romantic, symphony, string quartet, opera, conservatory, commission, arpeggio, cadenza, ballet, march, fanfare	In class composer study and worksheet – Formative Quiz – Summative Formative sample question THE NUTCRACKER is_______________. a. a ballet b. an opera c. an oratorio d. a plainsong chant Summative sample question True or False: Brahms never wrote an opera.
2 – INTO THE WOODS	MU:Pr4.2.8 MU:Pr6.1.8 MU:Re7.2.8 MU:Re9.1.8 MU:Cn10.1.8 MU:Cn11.1.8 TH:Cr.1.1.8 TH:Cr2.1.8 TH:Cr3.1.8	**Recorded performances** • What is the literary inspiration for the INTO THE WOODS? **Stephen Sondheim and James Lapine** • Who wrote INTO THE WOODS? • How did Sondheim change musical theatre? **Creating a show** • How do you get a show to Broadway?	In class viewing and discussion – Formative Opinion paragraph – Formative After viewing the opening scene of two different productions, which recording of INTO THE WOODS would you like to continue with? Give at least three reasons, and be specific.

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CURRICULUM FRAMEWORK

COURSE: Music **GRADE: 8**

	TH:Pr4.1.8 TH:Pr6.1.8 TH:Re8.1.8 TH:Re9.1.8 TH:Cn11.1.8 TH:Cn11.2.8	**Analyze the performance** • What makes a performance interesting? **Cultural Tie-ins** • How do artists use their work to comment on social issues? **Content Specific Vocabulary** Musical theatre, sets, scrim, motif, theme, reprise, composer, lyricist, book, stage direction, golden age, objective, goal	Formative sample discussion: What is a motif? Why are motifs used in musicals? Summative performance task: Collaborating with a group, present a scene from INTO THE WOODS incorporating props and costume pieces. (Instructor-designed rubric.)
3 – GIANNI SCHICCHI	MU:Pr4.2.8 MU:Pr6.1.8 MU:Re7.2.8 MU:Re9.1.8 MU:Cn10.1.8 MU:Cn11.1.8 TH:Cr.1.1.8 TH:Cr2.1.8 TH:Cr3.1.8 TH:Pr4.1.8 TH:Pr6.1.8 TH:Re8.1.8 TH:Re9.1.8	**Intro to Italian opera** • How have Italian composers shaped opera? • Why is Puccini considered the last great opera composer? • What is the difference between opera and musical theatre? **Musical themes** • What are two major musical themes in GIANNI SCHICCHI? **Realism in opera (verismo)** • How do we respond differently to believable plots (as opposed to fantasy)?	In class viewing, note-taking, and discussion - Formative Formative sample discussion Why did Puccini choose to have Zita portrayed by a mezzo-soprano? Summative performance task Collaborating with a group – write, stage, and perform a scene from an imagined second act of GIANNI SCHICCHI. (Instructor-designed rubric.)

	TH:Cn11.1.8 TH:Cn11.2.8	**Content Specific Vocabulary** Opera, soprano, mezzo-soprano, alto, tenor, baritone, bass, verismo, acts, scenes	
4 – PHANTOM OF THE OPERA	TH:Re7.1.8 TH:Re8.1.8 TH:Re9.1.8 TH:Cn11.2.8	**Andrew Lloyd Webber** • What qualifies success? • Why is Andrew Lloyd Webber considered successful? **Opera vs. musical theatre** • What are differences between opera and musical theatre? • What are similarities between opera and musical theatre? **Technical choices** • How do you crash a chandelier to the stage every night? **Artistic Choices** • How much control does a director have? • How much freedom does a performer have? **Content Specific Vocabulary** Broadway, choreography, interpretation, audience etiquette, cadenza, classical, ensemble, corps de ballet, performance venue, production values, interpretation, vocal technique, stylistically appropriate	In class viewing, note-taking, and discussion – Formative Formative sample discussion Is the use of a flashback an effective choice for setting PHANTOM OF THE OPERA? Quiz – Summative Summative sample essay Which of the three productions (INTO THE WOODS, GIANNI SCHICCHI, or PHANTOM OF THE OPERA) did you enjoy most? Why? Give at least three reasons for your choice, and back up your answer with specific examples from the shows.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Communicative Arts **GRADE: 9**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Visual Art	VA: RE8.1.I VA: Re9.1.I VA:Cn10.1.I VA:Cr.1.1.I VA:Cr.1.2.II VA: Cr.2.1.I VA: Cr3.1.I VA:Cr3.1.II VA:Pr7.1.I VA:Re7.2.I VA:Re8.1.I VA:Cn10.1.I	**Module 1 – Elements of Art and Principles of Design** • How do you identify components of art? • What fields do we use to describe and analyze art? • How does knowing and using visual art vocabularies help us understand and interpret works of art? **Module 2 – Picasso Inspired Self Portrait** • How do people contribute to awareness and understanding of their lives and the lives of their communities through art-making? • How does art help us understand the lives of people of different times, places, and cultures? • How does art preserve aspects of life? • How does knowing the contexts, histories, and/pr traditions of art forms help us create works of art and design? • Why do artists follow or break from established traditions? **Module 3 – Mixed Media Collage** • How do artists and designers determine whether a particular direction in their work is effective? • How do artists and designers learn from trial and error?	Class Discussion of Works of Art: Formative Sample Discussion Question: Compare and contrast the way line is used in three paintings. Elements & Principals Worksheet: Summative Example: Create a written and visual definition for physical and visual texture. Portrait Sketch – Formative Class Critique – Formative Portrait Final Product – Summative Portrait Final Product Reflection – Summative. Reflection Example Question: Describe the way your portrait evidences inherent cultural, character, or personality traits.

TEACHER'S NAME: Rebecca Frankum **6/17**

		Content Specific Vocabulary Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture, Physical, Visual, Typeography, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast, Layer, Paste, Adhere	Collage – Formative Reflection – Formative Example question: How did beginning a project with no defined plan impact your final product?
2 – Film: History & Elements	MA:Cr1.1.I MA:Cr3.1.I MA:Pr4.1.I MA:Pr5.1.I MA:Re7.1.I MA:Re8.1.I MA:Re9.1.HS.I MA:Cn11.1.I	**Module 1 – History of Film** • How do media artists generate ideas? • How do media artists organize and develop ideas and models into process structures to achieve the desired end product? • How has the evolution of culture and technology impacted film? **Module 2 – Genre, Story, & Character** • How do we "read" media artworks and discern their relational components? • How do media artworks convey meaning and manage audience experience? How do media artists organize and develop ideas and models into process structures to achieve the desired end product? • How are creativity and innovation developed within and through media arts productions? • What connections can we make between Film and Language Arts? **Module 3 – Cinematography & Sound** • What is required to produce a media artwork that conveys purpose, meaning, and artistic quality? • How do media artists improve/refine their work? • How are complex media arts experiences constructed? **Module 4 - Editing** • How do media artists use various tools and techniques?	Quiz – Summative Genre Group Worksheet – Formative Character analysis – Summative Example: Using specific examples from the film, define a character using Speech, Thoughts, Looks, Taste & Preferences, Actions, etc. Story Chart and Short Answer - Summative Group Short Film – Summative Rubric example: Film clearly displayed an understanding of camera shots and angles. All

		• How do media artworks function to convey meaning and manage audience experience? **Module 5 – Analysis** • How does media arts relate to its various contexts, purposes, and values? • How does investigating these relationships inform and deepen the media artists understanding and work? **Content Specific Vocabulary** Film, Digital, Media Arts, Genre, Character, Story, Cinematography, Shots, Angles, Zoom, Pan, Medium, Wide, Close-up, Shot, Scene, Sequence, Sound, Synchronous, Diegetic, Transition, Fade, Wipe, Dissolve, On-Action, Continuity, Discontinuity, Dutch Tilt, Mise-en-Scene	required shots and angles were used in a clear, logical manner that made sense to the viewer in relation to the story. Group Short Film – Summative Rubric example: Camera shots and angles are pieced together in a logical manner, to propel the storyline, and illustrate character. Film Analysis Short Answer Questions – Formative Class Discussion - Formative

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Visual Art **GRADE: 8**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Elements of Art & Principles of Design	VA:Cr1.1.8 VA:Cr2.3.8	**Elements of Art & Principles of Design** • What are the components of art? • How do you identify components of art? • What fields do we use to describe and analyze art? • How does knowing and using visual art vocabularies help us understand and interpret works of art? **Content Specific Vocabulary** Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture, Physical, Visual, Typeography, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast	Worksheet – Summative Summative Sample: Provide a written definition for shape, as well as visual representation of both geometric and organic shape.
2 - Printmaking	VA:Cr1.1.8 VA:Cr2.1.8 VA:Cr2.2.8 VA:Cr2.3.8 VA:Cr3.1.8 VA:Pr5.1.8 VA:Pr7.1.8 VA:Re8.1.8	**Module 1 – Theme and Design** • How does design relate to theme? • What are copyright limitations of design? • How do artists and designers create works of art or design that effectively communicate? **Module 2 – Preparing and Cutting Linoleum** • Why is it important for safety and health to understand and follow correct procedures in handling materials, tools, and equipment? • How do you evaluate the status of linoleum cuts? **Module 3 – Printing and Labeling Edition** • What materials are needed for linoleum printing? • What are techniques for keeping prints clean and consistent? • How do you label and edition and what value does that give? **Content Specific Vocabulary** • Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture,	Sketch and Revisions – Formative Linoleum Proof – Formative Completed Linoleum Edition – Summative Rubric Sample: Cutting Technique: Student took great care to cut linoleum carefully. Areas are crisp without jagged edges. There are no stray cuts or accidental "slip" marks. All cutting was well crafted to produce a clean, clear image.

		Physical, Visual, Typeography, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast, Unity, Printmaking, Relief, Linoleum Cutter, Brayer, Ink Plate, Inking, Saturation, Edition, Proof, Emboss	
3 – Collage Self Portrait	VA:Cr:2.1.8 VA:Cr2.2.8 VA:Cr2.3.8 VA:Cr3.1.8 VA:Pr5.1.8 VA:Pr7.1.8 VA:Re8.1.8 VA:Re9.1.8	**Module 1 – Theme and Design** • How do your artistic choices convey messages of identity? • What role does persistence play in revising, refining, and developing art? • How do you contribute to an understanding of your life through art-making and self-representation? **Module 2 – Creation of Self Portrait** • What techniques can you apply to create work with a high level of craftsmanship and polish? • How does the presenting of artwork influence and shape ideas, beliefs, and experiences? **Module 3 – Reflection on Work** • How do life experiences influence the way you relate to art? • What do process and experience teach us? • How does one determine criteria for evaluating art? • How is a personal preference different from an evaluation? **Content Specific Vocabulary** • Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture, Physical, Visual, Typeography, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast, Unity, Adhere, Layer, Anatomy	Sketch and Revisions – Formative Collage Final Product – Summative Rubric Sample: Facial Features: Student accurately observed and relayed facial features. Eyes, nose, & mouth were not created stereotypically and are proportionally accurate. Written Reflection – Formative Formative Sample Question: Were you successful in creating a unique work of art that is reflective of your personality in some way? Explain.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Visual Art

GRADE: 8

TEACHER'S NAME: Rebecca Frankum

6/17

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: VISUAL ART **GRADE: 6**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Elements of Art & Principles of Design	VA:Re7.2.6 VA:Re:8.1.6 VA:Re9.1.6	**Elements of Art & Principles of Design** • What are the components of art? • How do you identify components of art? • What fields do we use to describe and analyze art? • How does knowing and using visual art vocabulary aid in the understanding and interpretation of art? **Content Specific Vocabulary** Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture, Physical, Visual, Typeography, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast	Worksheet – Summative Summative Sample: Provide a written definition for shape, as well as visual representation of both geometric and organic shape.
2 – Colored Pencil Techniques and Drawing	VA:Cr2.1.6 VA:Re8.1.6 VA:Re9.1.6	**Module 1 – Colored Pencil Techniques** • How can colored pencils be used to create visual texture? • How can an artist learn from trial and error? **Module 2 – Planning and Sketching for Drawing** • How does an artist or designer determine whether a particular direction in their work is effective? • How is a personal preference different from an evaluation? • What elements create a successful composition? **Module 3 – Colored Pencil Drawing/Final Product** • How can colored pencils be used to create visual texture? • How does media choice affect an artwork? • Why do certain themes recur in art? **Module 4 – Class Critique** • What can we learn from studying the artwork of others? • How and why does choice of composition affect an artwork?	Worksheet – Formative Sketch – Formative Colored Pencil Drawing – Summative Rubric example: Visual texture was achieved through the artists' inclusion of several colored pencil techniques such as scumbling, blending, hatching, and stippling.

		• Why is exhibiting artwork an important part of an artist's creative process? **Content Specific Vocabulary** Hatching, Cross Hatching, Scumbling, Filling, Blending, Stippling, Composition, Value, Line, Form, Shape, Space, Positive, Negative, Craftsmanship, Texture	Class Critique – Formative Example discussion questions: What elements of art or principles of design do you see evidenced in a work of art? How did the artist express themselves through their artwork?

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: **Visual Art** **GRADE: 7**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Elements of Art & Principles of Design	VA:Cr.2.3.7 VA:Re.8.1.7	**Elements of Art & Principles of Design** • What are the components of art? • How do you identify components of art? • What fields do we use to describe and analyze art? **Content Specific Vocabulary** Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture, Physical, Visual, Typeography, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast	Worksheet – Summative Summative Sample: Provide a written definition for shape, as well as visual representation of both geometric and organic shape.
2 - Value	VA:Cr1.1.7 VA:Cr2.1.7 VA:Cr2.3.7 VA:Cr3.1.7	**Module 1 – Value Scales in Gray & Color** • How does value contribute to art? • What techniques can be applied to create value? **Module 2 – Value Landscape Sketch** • How do I use my art skills and knowledge to create a successful composition? • How do artists learn from trial and error? • How can I apply principles of atmosphere, value, and design to create the illusion of depth? **Module 3 – Value Landscape Painting** • How do artists create works that effectively communicate? • What role does persistence play in revising, refining, and developing work? • How does craftsmanship influence the outcome of a final artwork? **Content Specific Vocabulary** • Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture, Physical, Visual, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast, Unity, Atmosphere, Tone, Shade, Tint, Mixing, Blending	Value Gray Scales/Color Scales – Formative Landscape sketch - Formative Landscape Painting - Summative Rubric Sample: Value scale demonstrates 8 distinct values, completely and evenly rendered with equal steps between values.

3 – Collage Self Portrait		**Module 1 – Theme and Design** • How do your artistic choices convey messages of identity? • How do you contribute to an understanding of your life through art-making and self-representation? **Module 2 – Creation of Self Portrait** • What techniques can you apply to create work with a high level of craftsmanship and polish? • How does the presenting of artwork influence and shape ideas, beliefs, and experiences? **Module 3 – Reflection on Work** • How do life experiences influence the way you relate to art? • What do process and experience teach us? • How does one determine criteria for evaluating art? • How is a personal preference different from an evaluation? **Content Specific Vocabulary** • Line, Form, Shape, Geometric, Organic, Space, Positive, Negative, Value, Color, Texture, Physical, Visual, Typeography, Balance, Alignment, Emphasis, Proportion, Movement, Pattern, Contrast, Unity, Adhere, Layer, Anatomy	Sketch and Revisions – Formative Collage Final Product – Summative Rubric Sample: Background design is integrated and effective because elements (line, shape, color, etc.) are varied, repeated, and/or overlapped to engage the entire space. Reflection – Formative Formative Question Examples: Explain how your work shows unity. What message(s) are you communicating to your audience through your artwork? Using specific examples, explain how you communicate that idea through your artwork.

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CURRICULUM FRAMEWORK

COURSE: **World Art** **GRADE: 10,11,12**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 – Tibetan Mandala	VA:Cr2.1.II VA:Cr3.1.II VA:Pr6.1.II VA:Pr7.1.II VA:Re7.2.II VA:Re7.2.III VA:Re8.1.II VA:Cn10.1.II Va:Cn10.1.III VA:Cn11.1.II	**Module 1 – Mandala History and Cultural Context** • How do elements and practices of Buddhism relate to mandala practices? • What cultural connections and contexts do mandalas bridge? • How does art relate to emotional health? • How does art help us understand the lives of people of different times, places, and cultures? **Module 2 – Mandala** • How does art preserve aspects of life? • How do people contribute to awareness and understanding of their lives and the lives of their communities through art-making? • What role does pattern and other principles of design play in the construction of a mandala? **Module 3 – Critique & Written Reflection** • What is the value of engaging in art criticism? • How do images influence the views of our community and our world? • How do life experiences influence the way you relate to art? **Content Specific Vocabulary** Line, Shape, Form, Texture, Color, Space, Value, Pattern, Symmetry, Radial, Concentric, Pyscho-Physical, Meditative, Balance, Contrast, unity, Harmony, Emphasis, Movement, Rhythm	Pattern worksheet – Formative Mandala layout – Formative Mandala Final product – Summative Rubric example: Pattern and balance were displayed exceptionally well. Patterns are consistent, varietal, and original. The mandalas composition is visually balanced as well as having radial symmetry. Mandala Critique and Reflection – Formative
2 – China Ming Dynasty Ceraimcs	VA:Cr2.1.II Va:Cr1.2.III VA:Cr3.1.I VA:Pr6.1.II	**Module 1 – Ming Dynasty and Asian Ceramics** • How has the cobalt and porcelain combination evolved over time in relation to cultures? • How is art used to impact the views of a society?	Ming History Short Answer Research – Summative

	VA:Pr7.1.II	**Module 2 – Cobalt & Porcelain Mixed Media Ceramics** • How do modern artistic practices change the aesthetics of a traditional practice? • How do artists and designers determine goals for designing or redesigning objects, places, or systems? • How does experimentation inform new artistic methods and techniques? **Content Specific Vocabulary** Ming, Dynasty, Ceramics, Porcelain, Shape, Space, Volume, Form, Characters, Line, Shape, Form, Texture, Visual, Physical, Balance, Concentric, Unity, Pattern, Emphasis, Movement	Gesso & Oil Pastel Ming Final Product - Summative
3 – Islamic Geometric Tile Design	VA:Cr2.1.II VA:Cr3.1.II VA:Pr6.1.II VA:Pr7.1.II VA:Re7.2.II VA:Re7.2.III VA:Re8.1.II VA:Cn10.1.II Va:Cn10.1.III VA:Cn11.1.II	**Module 1 – Islamic Tile Patterns** • How does knowing the contexts of histories, and traditions of art forms help us create works of art and design? • How does learning about art impact our perception of the world? **Module 2 – Islamic Tile Mixed Media** • Why do artists follow or break from established traditions? • How does art preserve aspects of life? • What challenges are we faced with when combining traditional elements with modern elements?	Worksheet Packet – Formative Islamic Tile Mixed Media Final Product Summative Rubric Example Student clearly laid at least one Islamic tile sample on the board. The tile pattern evidences high craftsmanship and polish and contributes positively to the composition.
4 – American Pop Art	VA:Cr2.1.II VA:Cr3.1.II	**Module 1 – Theme and Design** • How does design relate to theme?	Sketch and Revisions – Formative

	VA:Pr6.1.II VA:Pr7.1.II VA:Re7.2.II VA:Re7.2.III VA:Re8.1.II VA:Cn10.1.II Va:Cn10.1.III VA:Cn11.1.II	• What are copyright limitations of design? • How does pop art relate to both current and past culture? **Module 2 – Preparing and Cutting Linoleum** • How do artists and designers care for and maintain materials, tools, and equipment? • Why is it important for safety and health to understand and follow correct procedures in handling materials, tools, and equipment? • How do artists and designers determine whether a particular direction in their work is effective? **Module 3 – Printing and Labeling Edition** • What are techniques for establishing registration? • How do artists and designers learn from trial and error? **Content Specific Vocabulary** Line, Form, Shape, Space, Value, Texture, Color, Pattern, Linoleum, Cutter, Ink Plate, Block, Brayer, Emboss, Registration, Layer, Label, Edition, Limited Edition, Emphasis, Composition, Balance, Repetition	Linoleum Proof – Formative Completed Linoleum Edition – Summative Rubric Sample: Cutting Technique: Student took great care to cut linoleum carefully. Areas are crisp without jagged edges. There are no stray cuts or accidental "slip" marks. All cutting was well crafted to produce a clean, clear image.

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Diploma Programme

Mathematics HL guide

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The International Baccalaureate Organization (known as the IB) offers three high-quality and challenging educational programmes for a worldwide community of schools, aiming to create a better, more peaceful world. This publication is one of a range of materials produced to support these programmes.

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IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

IB learners strive to be:

Inquirers	They develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning will be sustained throughout their lives.
Knowledgeable	They explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines.
Thinkers	They exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions.
Communicators	They understand and express ideas and information confidently and creatively in more than one language and in a variety of modes of communication. They work effectively and willingly in collaboration with others.
Principled	They act with integrity and honesty, with a strong sense of fairness, justice and respect for the dignity of the individual, groups and communities. They take responsibility for their own actions and the consequences that accompany them.
Open-minded	They understand and appreciate their own cultures and personal histories, and are open to the perspectives, values and traditions of other individuals and communities. They are accustomed to seeking and evaluating a range of points of view, and are willing to grow from the experience.
Caring	They show empathy, compassion and respect towards the needs and feelings of others. They have a personal commitment to service, and act to make a positive difference to the lives of others and to the environment.
Risk-takers	They approach unfamiliar situations and uncertainty with courage and forethought, and have the independence of spirit to explore new roles, ideas and strategies. They are brave and articulate in defending their beliefs.
Balanced	They understand the importance of intellectual, physical and emotional balance to achieve personal well-being for themselves and others.
Reflective	They give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development.

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Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This guide can be found on the subject page of the online curriculum centre (OCC) at http://occ.ibo.org, a password-protected IB website designed to support IB teachers. It can also be purchased from the IB store at http://store.ibo.org.

Additional resources

Additional publications such as teacher support materials, subject reports, internal assessment guidance and grade descriptors can also be found on the OCC. Specimen and past examination papers as well as markschemes can be purchased from the IB store.

Teachers are encouraged to check the OCC for additional resources created or used by other teachers. Teachers can provide details of useful resources, for example: websites, books, videos, journals or teaching ideas.

First examinations 2014

The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme hexagon

The course is presented as six academic areas enclosing a central core (see figure 1). It encourages the concurrent study of a broad range of academic areas. Students study: two modern languages (or a modern language and a classical language); a humanities or social science subject; an experimental science; mathematics; one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.

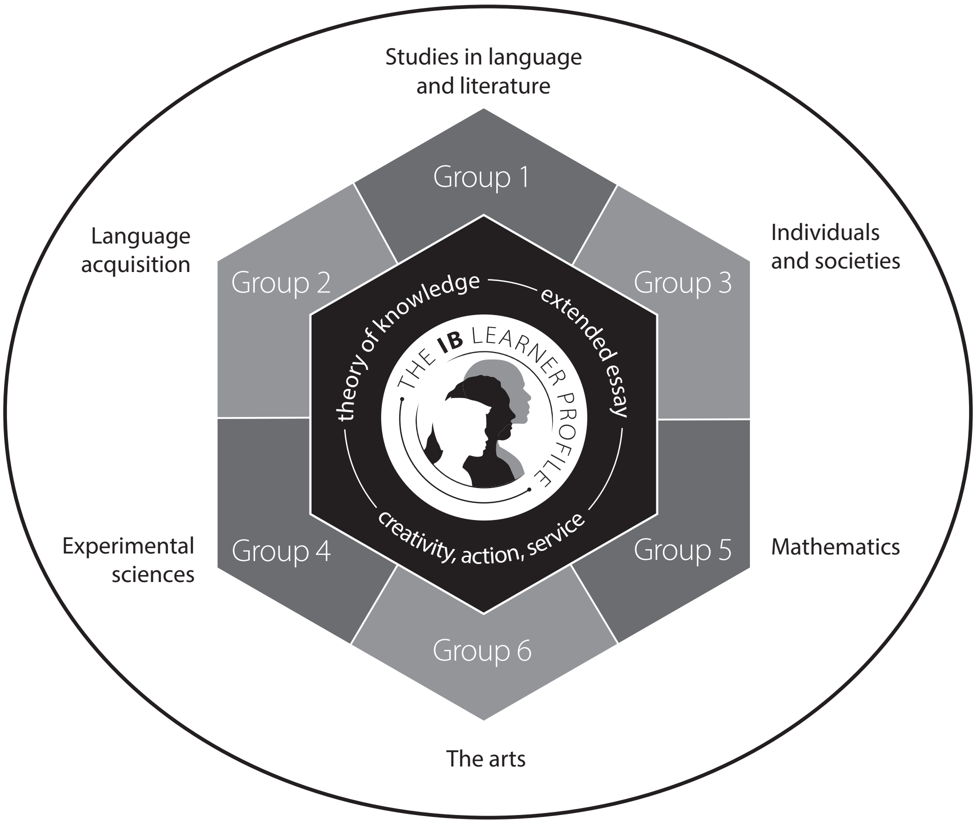

Figure 1

Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can choose a second subject from groups 1 to 5 instead of a group 6 subject. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers. The courses are available for examinations in English, French and Spanish, with the exception of groups 1 and 2 courses where examinations are in the language of study.

The core of the hexagon

All Diploma Programme students participate in the three course requirements that make up the core of the hexagon. Reflection on all these activities is a principle that lies at the heart of the thinking behind the Diploma Programme.

The theory of knowledge course encourages students to think about the nature of knowledge, to reflect on the process of learning in all the subjects they study as part of their Diploma Programme course, and to make connections across the academic areas. The extended essay, a substantial piece of writing of up to 4,000 words, enables students to investigate a topic of special interest that they have chosen themselves. It also encourages them to develop the skills of independent research that will be expected at university. Creativity, action, service involves students in experiential learning through a range of artistic, sporting, physical and service activities.

The IB mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IB, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

Nature of the subject

Introduction

The nature of mathematics can be summarized in a number of ways: for example, it can be seen as a well-defined body of knowledge, as an abstract system of ideas, or as a useful tool. For many people it is probably a combination of these, but there is no doubt that mathematical knowledge provides an important key to understanding the world in which we live. Mathematics can enter our lives in a number of ways: we buy produce in the market, consult a timetable, read a newspaper, time a process or estimate a length. Mathematics, for most of us, also extends into our chosen profession: visual artists need to learn about perspective; musicians need to appreciate the mathematical relationships within and between different rhythms; economists need to recognize trends in financial dealings; and engineers need to take account of stress patterns in physical materials. Scientists view mathematics as a language that is central to our understanding of events that occur in the natural world. Some people enjoy the challenges offered by the logical methods of mathematics and the adventure in reason that mathematical proof has to offer. Others appreciate mathematics as an aesthetic experience or even as a cornerstone of philosophy. This prevalence of mathematics in our lives, with all its interdisciplinary connections, provides a clear and sufficient rationale for making the study of this subject compulsory for students studying the full diploma.

Summary of courses available

Because individual students have different needs, interests and abilities, there are four different courses in mathematics. These courses are designed for different types of students: those who wish to study mathematics in depth, either as a subject in its own right or to pursue their interests in areas related to mathematics; those who wish to gain a degree of understanding and competence to understand better their approach to other subjects; and those who may not as yet be aware how mathematics may be relevant to their studies and in their daily lives. Each course is designed to meet the needs of a particular group of students. Therefore, great care should be taken to select the course that is most appropriate for an individual student.

In making this selection, individual students should be advised to take account of the following factors:

- their own abilities in mathematics and the type of mathematics in which they can be successful
- their own interest in mathematics and those particular areas of the subject that may hold the most interest for them
- their other choices of subjects within the framework of the Diploma Programme
- their academic plans, in particular the subjects they wish to study in future
- their choice of career.

Teachers are expected to assist with the selection process and to offer advice to students.

Mathematical studies SL

This course is available only at standard level, and is equivalent in status to mathematics SL, but addresses different needs. It has an emphasis on applications of mathematics, and the largest section is on statistical techniques. It is designed for students with varied mathematical backgrounds and abilities. It offers students opportunities to learn important concepts and techniques and to gain an understanding of a wide variety of mathematical topics. It prepares students to be able to solve problems in a variety of settings, to develop more sophisticated mathematical reasoning and to enhance their critical thinking. The individual project is an extended piece of work based on personal research involving the collection, analysis and evaluation of data. Students taking this course are well prepared for a career in social sciences, humanities, languages or arts. These students may need to utilize the statistics and logical reasoning that they have learned as part of the mathematical studies SL course in their future studies.

Mathematics SL

This course caters for students who already possess knowledge of basic mathematical concepts, and who are equipped with the skills needed to apply simple mathematical techniques correctly. The majority of these students will expect to need a sound mathematical background as they prepare for future studies in subjects such as chemistry, economics, psychology and business administration.

Mathematics HL

This course caters for students with a good background in mathematics who are competent in a range of analytical and technical skills. The majority of these students will be expecting to include mathematics as a major component of their university studies, either as a subject in its own right or within courses such as physics, engineering and technology. Others may take this subject because they have a strong interest in mathematics and enjoy meeting its challenges and engaging with its problems.

Further mathematics HL

This course is available only at higher level. It caters for students with a very strong background in mathematics who have attained a high degree of competence in a range of analytical and technical skills, and who display considerable interest in the subject. Most of these students will expect to study mathematics at university, either as a subject in its own right or as a major component of a related subject. The course is designed specifically to allow students to learn about a variety of branches of mathematics in depth and also to appreciate practical applications. It is expected that students taking this course will also be taking mathematics HL.

Note: Mathematics HL is an ideal course for students expecting to include mathematics as a major component of their university studies, either as a subject in its own right or within courses such as physics, engineering or technology. It should not be regarded as necessary for such students to study further mathematics HL. Rather, further mathematics HL is an optional course for students with a particular aptitude and interest in mathematics, enabling them to study some wider and deeper aspects of mathematics, but is by no means a necessary qualification to study for a degree in mathematics.

Mathematics HL—course details

The course focuses on developing important mathematical concepts in a comprehensible, coherent and rigorous way. This is achieved by means of a carefully balanced approach. Students are encouraged to apply their mathematical knowledge to solve problems set in a variety of meaningful contexts. Development of each topic should feature justification and proof of results. Students embarking on this course should expect to develop insight into mathematical form and structure, and should be intellectually equipped to appreciate the links between concepts in different topic areas. They should also be encouraged to develop the skills needed to continue their mathematical growth in other learning environments.

The internally assessed component, the exploration, offers students the opportunity for developing independence in their mathematical learning. Students are encouraged to take a considered approach to various mathematical activities and to explore different mathematical ideas. The exploration also allows students to work without the time constraints of a written examination and to develop the skills they need for communicating mathematical ideas.

This course is a demanding one, requiring students to study a broad range of mathematical topics through a number of different approaches and to varying degrees of depth. Students wishing to study mathematics in a less rigorous environment should therefore opt for one of the standard level courses, mathematics SL or mathematical studies SL. Students who wish to study an even more rigorous and demanding course should consider taking further mathematics HL in addition to mathematics HL.

Prior learning

Mathematics is a linear subject, and it is expected that most students embarking on a Diploma Programme (DP) mathematics course will have studied mathematics for at least 10 years. There will be a great variety of topics studied, and differing approaches to teaching and learning. Thus students will have a wide variety of skills and knowledge when they start the mathematics HL course. Most will have some background in arithmetic, algebra, geometry, trigonometry, probability and statistics. Some will be familiar with an inquiry approach, and may have had an opportunity to complete an extended piece of work in mathematics.

At the beginning of the syllabus section there is a list of topics that are considered to be prior learning for the mathematics HL course. It is recognized that this may contain topics that are unfamiliar to some students, but it is anticipated that there may be other topics in the syllabus itself that these students have already encountered. Teachers should plan their teaching to incorporate topics mentioned that are unfamiliar to their students.

Links to the Middle Years Programme

The prior learning topics for the DP courses have been written in conjunction with the Middle Years Programme (MYP) mathematics guide. The approaches to teaching and learning for DP mathematics build on the approaches used in the MYP. These include investigations, exploration and a variety of different assessment tools.

A continuum document called *Mathematics: The MYP–DP continuum* (November 2010) is available on the DP mathematics home pages of the OCC. This extensive publication focuses on the alignment of mathematics across the MYP and the DP. It was developed in response to feedback provided by IB World Schools, which expressed the need to articulate the transition of mathematics from the MYP to the DP. The publication also highlights the similarities and differences between MYP and DP mathematics, and is a valuable resource for teachers.

Mathematics and theory of knowledge

The *Theory of knowledge guide* (March 2006) identifies four ways of knowing, and it could be claimed that these all have some role in the acquisition of mathematical knowledge. While perhaps initially inspired by data from sense perception, mathematics is dominated by reason, and some mathematicians argue that their subject is a language, that it is, in some sense, universal. However, there is also no doubt that mathematicians perceive beauty in mathematics, and that emotion can be a strong driver in the search for mathematical knowledge.

As an area of knowledge, mathematics seems to supply a certainty perhaps missing in other disciplines. This may be related to the "purity" of the subject that makes it sometimes seem divorced from reality. However, mathematics has also provided important knowledge about the world, and the use of mathematics in science and technology has been one of the driving forces for scientific advances.

Despite all its undoubted power for understanding and change, mathematics is in the end a puzzling phenomenon. A fundamental question for all knowers is whether mathematical knowledge really exists independently of our thinking about it. Is it there "waiting to be discovered" or is it a human creation?

Students' attention should be drawn to questions relating theory of knowledge (TOK) and mathematics, and they should be encouraged to raise such questions themselves, in mathematics and TOK classes. This includes questioning all the claims made above. Examples of issues relating to TOK are given in the "Links" column of the syllabus. Teachers could also discuss questions such as those raised in the "Areas of knowledge" section of the TOK guide.

Mathematics and the international dimension

Mathematics is in a sense an international language, and, apart from slightly differing notation, mathematicians from around the world can communicate within their field. Mathematics transcends politics, religion and nationality, yet throughout history great civilizations owe their success in part to their mathematicians being able to create and maintain complex social and architectural structures.

Despite recent advances in the development of information and communication technologies, the global exchange of mathematical information and ideas is not a new phenomenon and has been essential to the progress of mathematics. Indeed, many of the foundations of modern mathematics were laid many centuries ago by Arabic, Greek, Indian and Chinese civilizations, among others. Teachers could use timeline websites to show the contributions of different civilizations to mathematics, but not just for their mathematical content. Illustrating the characters and personalities of the mathematicians concerned and the historical context in which they worked brings home the human and cultural dimension of mathematics.

The importance of science and technology in the everyday world is clear, but the vital role of mathematics is not so well recognized. It is the language of science, and underpins most developments in science and technology. A good example of this is the digital revolution, which is transforming the world, as it is all based on the binary number system in mathematics.

Many international bodies now exist to promote mathematics. Students are encouraged to access the extensive websites of international mathematical organizations to enhance their appreciation of the international dimension and to engage in the global issues surrounding the subject.

Examples of global issues relating to international-mindedness (**Int**) are given in the "Links" column of the syllabus.

Aims

Group 5 aims

The aims of all mathematics courses in group 5 are to enable students to:

1. enjoy mathematics, and develop an appreciation of the elegance and power of mathematics
2. develop an understanding of the principles and nature of mathematics
3. communicate clearly and confidently in a variety of contexts
4. develop logical, critical and creative thinking, and patience and persistence in problem-solving
5. employ and refine their powers of abstraction and generalization
6. apply and transfer skills to alternative situations, to other areas of knowledge and to future developments
7. appreciate how developments in technology and mathematics have influenced each other
8. appreciate the moral, social and ethical implications arising from the work of mathematicians and the applications of mathematics
9. appreciate the international dimension in mathematics through an awareness of the universality of mathematics and its multicultural and historical perspectives
10. appreciate the contribution of mathematics to other disciplines, and as a particular "area of knowledge" in the TOK course.

Assessment objectives

Problem-solving is central to learning mathematics and involves the acquisition of mathematical skills and concepts in a wide range of situations, including non-routine, open-ended and real-world problems. Having followed a DP mathematics HL course, students will be expected to demonstrate the following.

1. **Knowledge and understanding**: recall, select and use their knowledge of mathematical facts, concepts and techniques in a variety of familiar and unfamiliar contexts.
2. **Problem-solving**: recall, select and use their knowledge of mathematical skills, results and models in both real and abstract contexts to solve problems.
3. **Communication and interpretation**: transform common realistic contexts into mathematics; comment on the context; sketch or draw mathematical diagrams, graphs or constructions both on paper and using technology; record methods, solutions and conclusions using standardized notation.
4. **Technology**: use technology, accurately, appropriately and efficiently both to explore new ideas and to solve problems.
5. **Reasoning**: construct mathematical arguments through use of precise statements, logical deduction and inference, and by the manipulation of mathematical expressions.
6. **Inquiry approaches**: investigate unfamiliar situations, both abstract and real-world, involving organizing and analysing information, making conjectures, drawing conclusions and testing their validity.

Syllabus outline

Syllabus component	Teaching hours HL
All topics are compulsory. Students must study all the sub-topics in each of the topics in the syllabus as listed in this guide. Students are also required to be familiar with the topics listed as prior learning.	
Topic 1 Algebra	30
Topic 2 Functions and equations	22
Topic 3 Circular functions and trigonometry	22
Topic 4 Vectors	24
Topic 5 Statistics and probability	36
Topic 6 Calculus	48
Option syllabus content Students must study all the sub-topics in one of the following options as listed in the syllabus details. **Topic 7** Statistics and probability **Topic 8** Sets, relations and groups **Topic 9** Calculus **Topic 10** Discrete mathematics	48
Mathematical exploration Internal assessment in mathematics HL is an individual exploration. This is a piece of written work that involves investigating an area of mathematics.	10
Total teaching hours	**240**

Approaches to the teaching and learning of mathematics HL

Throughout the DP mathematics HL course, students should be encouraged to develop their understanding of the methodology and practice of the discipline of mathematics. The processes of **mathematical inquiry**, **mathematical modelling and applications** and the **use of technology** should be introduced appropriately. These processes should be used throughout the course, and not treated in isolation.

Mathematical inquiry

The IB learner profile encourages learning by experimentation, questioning and discovery. In the IB classroom, students should generally learn mathematics by being active participants in learning activities rather than recipients of instruction. Teachers should therefore provide students with opportunities to learn through mathematical inquiry. This approach is illustrated in figure 2.

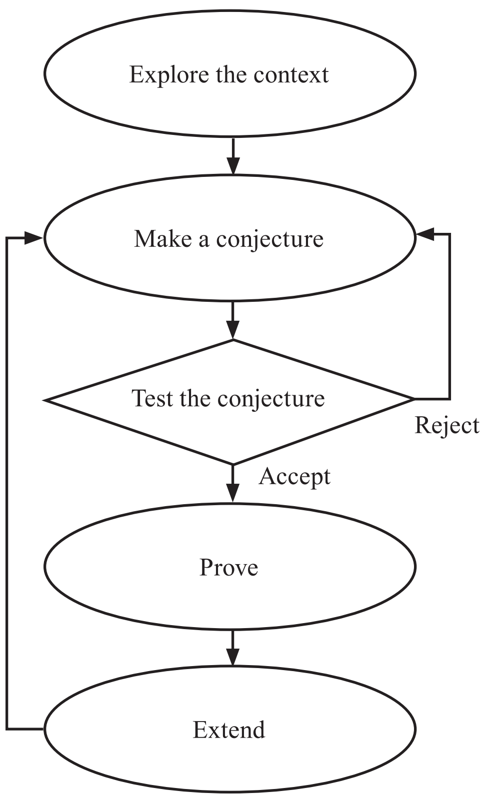

Figure 2

Mathematical modelling and applications

Students should be able to use mathematics to solve problems in the real world. Engaging students in the mathematical modelling process provides such opportunities. Students should develop, apply and critically analyse models. This approach is illustrated in figure 3.

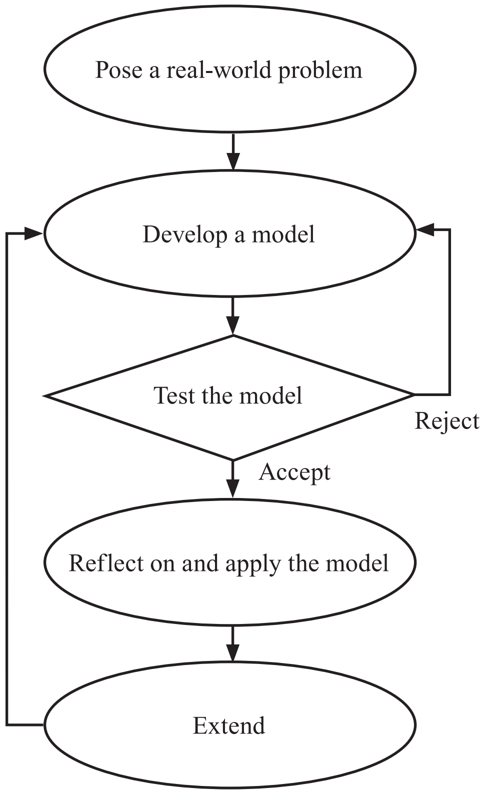

Figure 3

Technology

Technology is a powerful tool in the teaching and learning of mathematics. Technology can be used to enhance visualization and support student understanding of mathematical concepts. It can assist in the collection, recording, organization and analysis of data. Technology can increase the scope of the problem situations that are accessible to students. The use of technology increases the feasibility of students working with interesting problem contexts where students reflect, reason, solve problems and make decisions.

As teachers tie together the unifying themes of **mathematical inquiry**, **mathematical modelling and applications** and the **use of technology**, they should begin by providing substantial guidance, and then gradually encourage students to become more independent as inquirers and thinkers. IB students should learn to become strong communicators through the language of mathematics. Teachers should create a safe learning environment in which students are comfortable as risk-takers.

Teachers are encouraged to relate the mathematics being studied to other subjects and to the real world, especially topics that have particular relevance or are of interest to their students. Everyday problems and questions should be drawn into the lessons to motivate students and keep the material relevant; suggestions are provided in the "Links" column of the syllabus. The mathematical exploration offers an opportunity to investigate the usefulness, relevance and occurrence of mathematics in the real world and will add an extra dimension to the course. The emphasis is on communication by means of mathematical forms (for example, formulae, diagrams, graphs and so on) with accompanying commentary. Modelling, investigation, reflection, personal engagement and mathematical communication should therefore feature prominently in the DP mathematics classroom.

For further information on "Approaches to teaching a DP course", please refer to the publication *The Diploma Programme: From principles into practice* (April 2009). To support teachers, a variety of resources can be found on the OCC and details of workshops for professional development are available on the public website.

Format of the syllabus

- **Content**: this column lists, under each topic, the sub-topics to be covered.
- **Further guidance**: this column contains more detailed information on specific sub-topics listed in the content column. This clarifies the content for examinations.
- **Links**: this column provides useful links to the aims of the mathematics HL course, with suggestions for discussion, real-life examples and ideas for further investigation. **These suggestions are only a guide for introducing and illustrating the sub-topic and are not exhaustive.** Links are labelled as follows.

  Appl real-life examples and links to other DP subjects

  Aim 8 moral, social and ethical implications of the sub-topic

  Int international-mindedness

  TOK suggestions for discussion

Note that any syllabus references to other subject guides given in the "Links" column are correct for the current (2012) published versions of the guides.

Notes on the syllabus

- Formulae are only included in this document where there may be some ambiguity. All formulae required for the course are in the mathematics HL and further mathematics HL formula booklet.
- The term "technology" is used for any form of calculator or computer that may be available. However, there will be restrictions on which technology may be used in examinations, which will be noted in relevant documents.
- The terms "analysis" and "analytic approach" are generally used when referring to an approach that does not use technology.

Course of study

The content of all six topics and one of the option topics in the syllabus must be taught, although not necessarily in the order in which they appear in this guide. Teachers are expected to construct a course of study that addresses the needs of their students and includes, where necessary, the topics noted in prior learning.

Integration of the mathematical exploration

Work leading to the completion of the exploration should be integrated into the course of study. Details of how to do this are given in the section on internal assessment and in the teacher support material.

Time allocation

The recommended teaching time for higher level courses is 240 hours. For mathematics HL, it is expected that 10 hours will be spent on work for the exploration. The time allocations given in this guide are approximate, and are intended to suggest how the remaining 230 hours allowed for the teaching of the syllabus might be allocated. However, the exact time spent on each topic depends on a number of factors, including the background knowledge and level of preparedness of each student. Teachers should therefore adjust these timings to correspond to the needs of their students.

Use of calculators

Students are expected to have access to a graphic display calculator (GDC) at all times during the course. The minimum requirements are reviewed as technology advances, and updated information will be provided to schools. It is expected that teachers and schools monitor calculator use with reference to the calculator policy. Regulations covering the types of calculators allowed in examinations are provided in the *Handbook of procedures for the Diploma Programme*. Further information and advice is provided in the *Mathematics HL/SL: Graphic display calculators teacher support material* (May 2005) and on the OCC.

Mathematics HL and further mathematics HL formula booklet

Each student is required to have access to a clean copy of this booklet during the examination. It is recommended that teachers ensure students are familiar with the contents of this document from the beginning of the course. It is the responsibility of the school to download a copy from IBIS or the OCC, check that there are no printing errors, and ensure that there are sufficient copies available for all students.

Teacher support materials

A variety of teacher support materials will accompany this guide. These materials will include guidance for teachers on the introduction, planning and marking of the exploration, and specimen examination papers and markschemes.

Command terms and notation list

Teachers and students need to be familiar with the IB notation and the command terms, as these will be used without explanation in the examination papers. The “Glossary of command terms” and “Notation list” appear as appendices in this guide.

Prior learning topics

As noted in the previous section on prior learning, it is expected that all students have extensive previous mathematical experiences, but these will vary. It is expected that mathematics HL students will be familiar with the following topics before they take the examinations, because questions assume knowledge of them. Teachers must therefore ensure that any topics listed here that are unknown to their students at the start of the course are included at an early stage. They should also take into account the existing mathematical knowledge of their students to design an appropriate course of study for mathematics HL. This table lists the knowledge, together with the syllabus content, that is essential to successful completion of the mathematics HL course.

Students must be familiar with SI (*Système International*) units of length, mass and time, and their derived units.

Topic	Content
Number	Routine use of addition, subtraction, multiplication and division, using integers, decimals and fractions, including order of operations. Rational exponents. Simplification of expressions involving roots (surds or radicals), including rationalizing the denominator. Prime numbers and factors (divisors), including greatest common divisors and least common multiples. Simple applications of ratio, percentage and proportion, linked to similarity. Definition and elementary treatment of absolute value (modulus), $\lvert a \rvert$. Rounding, decimal approximations and significant figures, including appreciation of errors. Expression of numbers in standard form (scientific notation), that is, $a \times 10^k$, $1 \le a < 10$, $k \in \mathbb{Z}$.
Sets and numbers	Concept and notation of sets, elements, universal (reference) set, empty (null) set, complement, subset, equality of sets, disjoint sets. Operations on sets: union and intersection. Commutative, associative and distributive properties. Venn diagrams. Number systems: natural numbers; integers, $\mathbb{Z}$; rationals, $\mathbb{Q}$, and irrationals; real numbers, $\mathbb{R}$. Intervals on the real number line using set notation and using inequalities. Expressing the solution set of a linear inequality on the number line and in set notation. Mappings of the elements of one set to another; sets of ordered pairs.

Topic	Content
Algebra	Manipulation of linear and quadratic expressions, including factorization, expansion, completing the square and use of the formula. Rearrangement, evaluation and combination of simple formulae. Examples from other subject areas, particularly the sciences, should be included. Linear functions, their graphs, gradients and y-intercepts. Addition and subtraction of simple algebraic fractions. The properties of order relations: $<$, $\le$, $>$, $\ge$. Solution of linear equations and inequalities in one variable, including cases with rational coefficients. Solution of quadratic equations and inequalities, using factorization and completing the square. Solution of simultaneous linear equations in two variables.
Trigonometry	Angle measurement in degrees. Compass directions. Right-angle trigonometry. Simple applications for solving triangles. Pythagoras' theorem and its converse.
Geometry	Simple geometric transformations: translation, reflection, rotation, enlargement. Congruence and similarity, including the concept of scale factor of an enlargement. The circle, its centre and radius, area and circumference. The terms arc, sector, chord, tangent and segment. Perimeter and area of plane figures. Properties of triangles and quadrilaterals, including parallelograms, rhombuses, rectangles, squares, kites and trapeziums (trapezoids); compound shapes. Volumes of cuboids, pyramids, spheres, cylinders and cones. Classification of prisms and pyramids, including tetrahedra.
Coordinate geometry	Elementary geometry of the plane, including the concepts of dimension for point, line, plane and space. The equation of a line in the form $y = mx + c$. Parallel and perpendicular lines, including $m_1 = m_2$ and $m_1 m_2 = -1$. The Cartesian plane: ordered pairs (x, y), origin, axes. Mid-point of a line segment and distance between two points in the Cartesian plane.
Statistics and probability	Descriptive statistics: collection of raw data, display of data in pictorial and diagrammatic forms, including frequency histograms, cumulative frequency graphs. Obtaining simple statistics from discrete and continuous data, including mean, median, mode, quartiles, range, interquartile range and percentiles. Calculating probabilities of simple events.

Syllabus content

Topic 1—Core: Algebra

30 hours

The aim of this topic is to introduce students to some basic algebraic concepts and applications.

	Content	Further guidance	Links
1.1	Arithmetic sequences and series; sum of finite arithmetic series; geometric sequences and series; sum of finite and infinite geometric series. Sigma notation. Applications.	Sequences can be generated and displayed in several ways, including recursive functions. Link infinite geometric series with limits of convergence in 6.1. Examples include compound interest and population growth.	**Int:** The chess legend (Sissa ibn Dahir). **Int:** Aryabhatta is sometimes considered the “father of algebra”. Compare with al-Khawarizmi. **Int:** The use of several alphabets in mathematical notation (eg first term and common difference of an arithmetic sequence). **TOK:** Mathematics and the knower. To what extent should mathematical knowledge be consistent with our intuition? **TOK:** Mathematics and the world. Some mathematical constants (π , e, ϕ , Fibonacci numbers) appear consistently in nature. What does this tell us about mathematical knowledge? **TOK:** Mathematics and the knower. How is mathematical intuition used as a basis for formal proof? (Gauss’ method for adding up integers from 1 to 100.) *(continued)*

	Content	Further guidance	Links
			(see notes above) **Aim 8:** Short-term loans at high interest rates. How can knowledge of mathematics result in individuals being exploited or protected from extortion? **Appl:** Physics 7.2, 13.2 (radioactive decay and nuclear physics).
1.2	Exponents and logarithms. Laws of exponents; laws of logarithms. Change of base.	Exponents and logarithms are further developed in 2.4.	**Appl:** Chemistry 18.1, 18.2 (calculation of pH and buffer solutions). **TOK:** The nature of mathematics and science. Were logarithms an invention or discovery? (This topic is an opportunity for teachers and students to reflect on "the nature of mathematics".)
1.3	Counting principles, including permutations and combinations. The binomial theorem: expansion of $(a+b)^n$, $n \in \mathbb{N}$. **Not required:** Permutations where some objects are identical. Circular arrangements. Proof of binomial theorem.	The ability to find $\binom{n}{r}$ and ${}^{n}P_{r}$ using both the formula and technology is expected. Link to 5.4. Link to 5.6, binomial distribution.	**TOK:** The nature of mathematics. The unforeseen links between Pascal's triangle, counting methods and the coefficients of polynomials. Is there an underlying truth that can be found linking these? **Int:** The properties of Pascal's triangle were known in a number of different cultures long before Pascal (eg the Chinese mathematician Yang Hui). **Aim 8:** How many different tickets are possible in a lottery? What does this tell us about the ethics of selling lottery tickets to those who do not understand the implications of these large numbers?

	Content	Further guidance	Links
1.4	Proof by mathematical induction.	Links to a wide variety of topics, for example, complex numbers, differentiation, sums of series and divisibility.	**TOK:** Nature of mathematics and science. What are the different meanings of induction in mathematics and science? **TOK:** Knowledge claims in mathematics. Do proofs provide us with completely certain knowledge? **TOK:** Knowledge communities. Who judges the validity of a proof?
1.5	Complex numbers: the number $\mathrm{i} = \sqrt{-1}$; the terms real part, imaginary part, conjugate, modulus and argument. Cartesian form $z = a + \mathrm{i}b$. Sums, products and quotients of complex numbers.	When solving problems, students may need to use technology.	**Appl:** Concepts in electrical engineering. Impedance as a combination of resistance and reactance; also apparent power as a combination of real and reactive powers. These combinations take the form $z = a + \mathrm{i}b$. **TOK:** Mathematics and the knower. Do the words imaginary and complex make the concepts more difficult than if they had different names? **TOK:** The nature of mathematics. Has "i" been invented or was it discovered? **TOK:** Mathematics and the world. Why does "i" appear in so many fundamental laws of physics?

	Content	Further guidance	Links
1.6	Modulus–argument (polar) form $z = r(\cos\theta + \mathrm{i}\sin\theta) = r\,\mathrm{cis}\,\theta = r\mathrm{e}^{\mathrm{i}\theta}$. The complex plane.	$r\mathrm{e}^{\mathrm{i}\theta}$ is also known as Euler's form. The ability to convert between forms is expected. The complex plane is also known as the Argand diagram.	**Appl:** Concepts in electrical engineering. Phase angle/shift, power factor and apparent power as a complex quantity in polar form. **TOK:** The nature of mathematics. Was the complex plane already there before it was used to represent complex numbers geometrically? **TOK:** Mathematics and the knower. Why might it be said that $\mathrm{e}^{\mathrm{i}\pi} + 1 = 0$ is beautiful?
1.7	Powers of complex numbers: de Moivre's theorem. n^{th} roots of a complex number.	Proof by mathematical induction for $n \in \mathbb{Z}^+$.	**TOK:** Reason and mathematics. What is mathematical reasoning and what role does proof play in this form of reasoning? Are there examples of proof that are not mathematical?
1.8	Conjugate roots of polynomial equations with real coefficients.	Link to 2.5 and 2.7.	
1.9	Solutions of systems of linear equations (a maximum of three equations in three unknowns), including cases where there is a unique solution, an infinity of solutions or no solution.	These systems should be solved using both algebraic and technological methods, eg row reduction. Systems that have solution(s) may be referred to as consistent. When a system has an infinity of solutions, a general solution may be required. Link to vectors in 4.7.	**TOK:** Mathematics, sense, perception and reason. If we can find solutions in higher dimensions, can we reason that these spaces exist beyond our sense perception?

Topic 2—Core: Functions and equations 22 hours

The aims of this topic are to explore the notion of function as a unifying theme in mathematics, and to apply functional methods to a variety of mathematical situations. It is expected that extensive use will be made of technology in both the development and the application of this topic.

	Content	Further guidance	Links
2.1	Concept of function $f: x \mapsto f(x)$: domain, range; image (value). Odd and even functions. Composite functions $f \circ g$. Identity function. One-to-one and many-to-one functions. Inverse function f^{-1}, including domain restriction. Self-inverse functions.	$(f \circ g)(x) = f(g(x))$. Link with 6.2. Link with 3.4. Link with 6.2.	**Int:** The notation for functions was developed by a number of different mathematicians in the 17^{th} and 18^{th} centuries. How did the notation we use today become internationally accepted? **TOK:** The nature of mathematics. Is mathematics simply the manipulation of symbols under a set of formal rules?

	Content	Further guidance	Links
2.2	The graph of a function; its equation $y = f(x)$. Investigation of key features of graphs, such as maximum and minimum values, intercepts, horizontal and vertical asymptotes and symmetry, and consideration of domain and range. The graphs of the functions $y = \|f(x)\|$ and $y = f(\|x\|)$. The graph of $y = \frac{1}{f(x)}$ given the graph of $y = f(x)$.	Use of technology to graph a variety of functions.	**TOK:** Mathematics and knowledge claims. Does studying the graph of a function contain the same level of mathematical rigour as studying the function algebraically (analytically)? **Appl:** Sketching and interpreting graphs; Geography SL/HL (geographic skills); Chemistry 11.3.1. **Int:** Bourbaki group analytical approach versus Mandlebrot visual approach.
2.3	Transformations of graphs: translations; stretches; reflections in the axes. The graph of the inverse function as a reflection in $y = x$.	Link to 3.4. Students are expected to be aware of the effect of transformations on both the algebraic expression and the graph of a function.	**Appl:** Economics SL/HL 1.1 (shift in demand and supply curves).
2.4	The rational function $x \mapsto \frac{ax+b}{cx+d}$, and its graph. The function $x \mapsto a^x$, $a > 0$, and its graph. The function $x \mapsto \log_a x$, $x > 0$, and its graph.	The reciprocal function is a particular case. Graphs should include both asymptotes and any intercepts with axes. Exponential and logarithmic functions as inverses of each other. Link to 6.2 and the significance of e. Application of concepts in 2.1, 2.2 and 2.3.	**Appl:** Geography SL/HL (geographic skills); Physics SL/HL 7.2 (radioactive decay); Chemistry SL/HL 16.3 (activation energy); Economics SL/HL 3.2 (exchange rates).

	Content	Further guidance	Links
2.5	Polynomial functions and their graphs. The factor and remainder theorems. The fundamental theorem of algebra.	The graphical significance of repeated factors. The relationship between the degree of a polynomial function and the possible numbers of x-intercepts.	
2.6	Solving quadratic equations using the quadratic formula. Use of the discriminant $\Delta = b^2 - 4ac$ to determine the nature of the roots. Solving polynomial equations both graphically and algebraically. Sum and product of the roots of polynomial equations. Solution of $a^x = b$ using logarithms. Use of technology to solve a variety of equations, including those where there is no appropriate analytic approach.	May be referred to as roots of equations or zeros of functions. Link the solution of polynomial equations to conjugate roots in 1.8. For the polynomial equation $\sum_{r=0}^{n} a_r x^r = 0$, the sum is $\frac{-a_{n-1}}{a_n}$, the product is $\frac{(-1)^n a_0}{a_n}$.	**Appl:** Chemistry 17.2 (equilibrium law). **Appl:** Physics 2.1 (kinematics). **Appl:** Physics 4.2 (energy changes in simple harmonic motion). **Appl:** Physics (HL only) 9.1 (projectile motion). **Aim 8:** The phrase "exponential growth" is used popularly to describe a number of phenomena. Is this a misleading use of a mathematical term?

	Content	Further guidance	Links
2.7	Solutions of $g(x) \geq f(x)$. Graphical or algebraic methods, for simple polynomials up to degree 3. Use of technology for these and other functions.		

Topic 3—Core: Circular functions and trigonometry — 22 hours

The aims of this topic are to explore the circular functions, to introduce some important trigonometric identities and to solve triangles using trigonometry.
On examination papers, radian measure should be assumed unless otherwise indicated, for example, by $x \mapsto \sin x^{\circ}$.

	Content	Further guidance	Links
3.1	The circle: radian measure of angles. Length of an arc; area of a sector.	Radian measure may be expressed as multiples of π, or decimals. Link with 6.2.	**Int:** The origin of degrees in the mathematics of Mesopotamia and why we use minutes and seconds for time.
3.2	Definition of $\cos\theta$, $\sin\theta$ and $\tan\theta$ in terms of the unit circle. Exact values of sin, cos and tan of $0, \frac{\pi}{6}, \frac{\pi}{4}, \frac{\pi}{3}, \frac{\pi}{2}$ and their multiples. Definition of the reciprocal trigonometric ratios $\sec\theta$, $\csc\theta$ and $\cot\theta$. Pythagorean identities: $\cos^2\theta + \sin^2\theta = 1$; $1 + \tan^2\theta = \sec^2\theta$; $1 + \cot^2\theta = \csc^2\theta$.		**TOK:** Mathematics and the knower. Why do we use radians? (The arbitrary nature of degree measure versus radians as real numbers and the implications of using these two measures on the shape of sinusoidal graphs.) **TOK:** Mathematics and knowledge claims. If trigonometry is based on right triangles, how can we sensibly consider trigonometric ratios of angles greater than a right angle? **Int:** The origin of the word "sine". **Appl:** Physics SL/HL 2.2 (forces and dynamics). **Appl:** Triangulation used in the Global Positioning System (GPS). **Int:** Why did Pythagoras link the study of music and mathematics? **Appl:** Concepts in electrical engineering. Generation of sinusoidal voltage.
3.3	Compound angle identities. Double angle identities. **Not required:** Proof of compound angle identities.	Derivation of double angle identities from compound angle identities. Finding possible values of trigonometric ratios without finding θ, for example, finding $\sin 2\theta$ given $\sin\theta$.	

(continued)

	Content	Further guidance	Links
3.4	Composite functions of the form $f(x) = a\sin(b(x+c)) + d$. Applications.		*(see notes above)* **TOK:** Mathematics and the world. Music can be expressed using mathematics. Does this mean that music is mathematical, that mathematics is musical or that both are reflections of a common "truth"? **Appl:** Physics SL/HL 4.1 (kinematics of simple harmonic motion).
3.5	The inverse functions $x \mapsto \arcsin x$, $x \mapsto \arccos x$, $x \mapsto \arctan x$; their domains and ranges; their graphs.		
3.6	Algebraic and graphical methods of solving trigonometric equations in a finite interval, including the use of trigonometric identities and factorization. **Not required:** The general solution of trigonometric equations.		**TOK:** Mathematics and knowledge claims. How can there be an infinite number of discrete solutions to an equation?
3.7	The cosine rule The sine rule including the ambiguous case. Area of a triangle as $\frac{1}{2}ab\sin C$. Applications.	Examples include navigation, problems in two and three dimensions, including angles of elevation and depression.	**TOK:** Nature of mathematics. If the angles of a triangle can add up to less than 180°, 180° or more than 180°, what does this tell us about the "fact" of the angle sum of a triangle and about the nature of mathematical knowledge? **Appl:** Physics SL/HL 1.3 (vectors and scalars); Physics SL/HL 2.2 (forces and dynamics). **Int:** The use of triangulation to find the curvature of the Earth in order to settle a dispute between England and France over Newton's gravity.

Topic 4—Core: Vectors — 24 hours

The aim of this topic is to introduce the use of vectors in two and three dimensions, and to facilitate solving problems involving points, lines and planes.

	Content	Further guidance	Links
4.1	Concept of a vector. Representation of vectors using directed line segments. Unit vectors; base vectors $\boldsymbol{i}, \boldsymbol{j}, \boldsymbol{k}$. Components of a vector: $\boldsymbol{v} = \begin{pmatrix} v_1 \\ v_2 \\ v_3 \end{pmatrix} = v_1\boldsymbol{i} + v_2\boldsymbol{j} + v_3\boldsymbol{k}$.		**Aim 8:** Vectors are used to solve many problems in position location. This can be used to save a lost sailor or destroy a building with a laser-guided bomb. **Appl:** Physics SL/HL 1.3 (vectors and scalars); Physics SL/HL 2.2 (forces and dynamics). **TOK:** Mathematics and knowledge claims. You can perform some proofs using different mathematical concepts. What does this tell us about mathematical knowledge?
	Algebraic and geometric approaches to the following: • the sum and difference of two vectors; • the zero vector $\boldsymbol{0}$, the vector $-\boldsymbol{v}$; • multiplication by a scalar, $k\boldsymbol{v}$; • magnitude of a vector, $\lvert\boldsymbol{v}\rvert$; • position vectors $\overrightarrow{OA} = \boldsymbol{a}$.	Proofs of geometrical properties using vectors.	
	$\overrightarrow{AB} = \boldsymbol{b} - \boldsymbol{a}$	Distance between points A and B is the magnitude of $\overrightarrow{AB}$.	

	Content	Further guidance	Links
4.2	The definition of the scalar product of two vectors. Properties of the scalar product: $\boldsymbol{v} \cdot \boldsymbol{w} = \boldsymbol{w} \cdot \boldsymbol{v}$; $\boldsymbol{u} \cdot (\boldsymbol{v} + \boldsymbol{w}) = \boldsymbol{u} \cdot \boldsymbol{v} + \boldsymbol{u} \cdot \boldsymbol{w}$; $(k\boldsymbol{v}) \cdot \boldsymbol{w} = k(\boldsymbol{v} \cdot \boldsymbol{w})$; $\boldsymbol{v} \cdot \boldsymbol{v} = \lvert\boldsymbol{v}\rvert^2$. The angle between two vectors. Perpendicular vectors; parallel vectors.	$\boldsymbol{v} \cdot \boldsymbol{w} = \lvert\boldsymbol{v}\rvert\lvert\boldsymbol{w}\rvert\cos\theta$, where θ is the angle between $\boldsymbol{v}$ and $\boldsymbol{w}$. Link to 3.6. For non-zero vectors, $\boldsymbol{v} \cdot \boldsymbol{w} = 0$ is equivalent to the vectors being perpendicular. For parallel vectors, $\lvert\boldsymbol{v} \cdot \boldsymbol{w}\rvert = \lvert\boldsymbol{v}\rvert\lvert\boldsymbol{w}\rvert$.	**Appl:** Physics SL/HL 2.2 (forces and dynamics). **TOK:** The nature of mathematics. Why this definition of scalar product?
4.3	Vector equation of a line in two and three dimensions: $\boldsymbol{r} = \boldsymbol{a} + \lambda\boldsymbol{b}$. Simple applications to kinematics. The angle between two lines.	Knowledge of the following forms for equations of lines. Parametric form: $x = x_0 + \lambda l$, $y = y_0 + \lambda m$, $z = z_0 + \lambda n$. Cartesian form: $\frac{x - x_0}{l} = \frac{y - y_0}{m} = \frac{z - z_0}{n}$.	**Appl:** Modelling linear motion in three dimensions. **Appl:** Navigational devices, eg GPS. **TOK:** The nature of mathematics. Why might it be argued that vector representation of lines is superior to Cartesian?
4.4	Coincident, parallel, intersecting and skew lines; distinguishing between these cases. Points of intersection.		

	Content	Further guidance	Links
4.5	The definition of the vector product of two vectors. Properties of the vector product: $\boldsymbol{v} \times \boldsymbol{w} = -\boldsymbol{w} \times \boldsymbol{v}$; $\boldsymbol{u} \times (\boldsymbol{v} + \boldsymbol{w}) = \boldsymbol{u} \times \boldsymbol{v} + \boldsymbol{u} \times \boldsymbol{w}$; $(k\boldsymbol{v}) \times \boldsymbol{w} = k(\boldsymbol{v} \times \boldsymbol{w})$; $\boldsymbol{v} \times \boldsymbol{v} = \boldsymbol{0}$. Geometric interpretation of $\lvert \boldsymbol{v} \times \boldsymbol{w} \rvert$.	$\boldsymbol{v} \times \boldsymbol{w} = \lvert \boldsymbol{v} \rvert \lvert \boldsymbol{w} \rvert \sin\theta\, \boldsymbol{n}$, where θ is the angle between $\boldsymbol{v}$ and $\boldsymbol{w}$ and $\boldsymbol{n}$ is the unit normal vector whose direction is given by the right-hand screw rule. Areas of triangles and parallelograms.	**Appl:** Physics SL/HL 6.3 (magnetic force and field).
4.6	Vector equation of a plane $\boldsymbol{r} = \boldsymbol{a} + \lambda \boldsymbol{b} + \mu \boldsymbol{c}$. Use of normal vector to obtain the form $\boldsymbol{r} \cdot \boldsymbol{n} = \boldsymbol{a} \cdot \boldsymbol{n}$. Cartesian equation of a plane $ax + by + cz = d$.		
4.7	Intersections of: a line with a plane; two planes; three planes. Angle between: a line and a plane; two planes.	Link to 1.9. Geometrical interpretation of solutions.	**TOK:** Mathematics and the knower. Why are symbolic representations of three-dimensional objects easier to deal with than visual representations? What does this tell us about our knowledge of mathematics in other dimensions?

Topic 5—Core: Statistics and probability

36 hours

The aim of this topic is to introduce basic concepts. It may be considered as three parts: manipulation and presentation of statistical data (5.1), the laws of probability (5.2–5.4), and random variables and their probability distributions (5.5–5.7). It is expected that most of the calculations required will be done on a GDC. The emphasis is on understanding and interpreting the results obtained. Statistical tables will no longer be allowed in examinations.

	Content	Further guidance	Links
5.1	Concepts of population, sample, random sample and frequency distribution of discrete and continuous data. Grouped data: mid-interval values, interval width, upper and lower interval boundaries. Mean, variance, standard deviation. **Not required:** Estimation of mean and variance of a population from a sample.	For examination purposes, in papers 1 and 2 data will be treated as the population. In examinations the following formulae should be used: $\mu = \frac{\sum_{i=1}^{k} f_i x_i}{n}$, $\sigma^2 = \frac{\sum_{i=1}^{k} f_i (x_i - \mu)^2}{n} = \frac{\sum_{i=1}^{k} f_i x_i^2}{n} - \mu^2$.	**TOK:** The nature of mathematics. Why have mathematics and statistics sometimes been treated as separate subjects? **TOK:** The nature of knowing. Is there a difference between information and data? **Aim 8:** Does the use of statistics lead to an overemphasis on attributes that can easily be measured over those that cannot? **Appl:** Psychology SL/HL (descriptive statistics); Geography SL/HL (geographic skills); Biology SL/HL 1.1.2 (statistical analysis). **Appl:** Methods of collecting data in real life (census versus sampling). **Appl:** Misleading statistics in media reports.

	Content	Further guidance	Links
5.2	Concepts of trial, outcome, equally likely outcomes, sample space (U) and event. The probability of an event A as $\mathrm{P}(A)=\frac{n(A)}{n(U)}$. The complementary events A and A' (not A). Use of Venn diagrams, tree diagrams, counting principles and tables of outcomes to solve problems.		**Aim 8:** Why has it been argued that theories based on the calculable probabilities found in casinos are pernicious when applied to everyday life (eg economics)? **Int:** The development of the mathematical theory of probability in 17^{th} century France.
5.3	Combined events; the formula for $\mathrm{P}(A\cup B)$. Mutually exclusive events.		
5.4	Conditional probability; the definition $\mathrm{P}(A\mid B)=\frac{\mathrm{P}(A\cap B)}{\mathrm{P}(B)}$. Independent events; the definition $\mathrm{P}(A\mid B)=\mathrm{P}(A)=\mathrm{P}(A\mid B')$. Use of Bayes' theorem for a maximum of three events.	Use of $\mathrm{P}(A\cap B)=\mathrm{P}(A)\mathrm{P}(B)$ to show independence.	**Appl:** Use of probability methods in medical studies to assess risk factors for certain diseases. **TOK:** Mathematics and knowledge claims. Is independence as defined in probabilistic terms the same as that found in normal experience?

	Content	Further guidance	Links
5.5	Concept of discrete and continuous random variables and their probability distributions.		**TOK:** Mathematics and the knower. To what extent can we trust samples of data?
	Definition and use of probability density functions.		
	Expected value (mean), mode, median, variance and standard deviation.	For a continuous random variable, a value at which the probability density function has a maximum value is called a mode.	
	Applications.	Examples include games of chance.	**Appl:** Expected gain to insurance companies.
5.6	Binomial distribution, its mean and variance.	Link to binomial theorem in 1.3.	**TOK:** Mathematics and the real world. Is the binomial distribution ever a useful model for an actual real-world situation?
	Poisson distribution, its mean and variance.	Conditions under which random variables have these distributions.	
	Not required: Formal proof of means and variances.		
5.7	Normal distribution.	Probabilities and values of the variable must be found using technology. The standardized value (z) gives the number of standard deviations from the mean.	**Appl:** Chemistry SL/HL 6.2 (collision theory); Psychology HL (descriptive statistics); Biology SL/HL 1.1.3 (statistical analysis). **Aim 8:** Why might the misuse of the normal distribution lead to dangerous inferences and conclusions? **TOK:** Mathematics and knowledge claims. To what extent can we trust mathematical models such as the normal distribution? **Int:** De Moivre's derivation of the normal distribution and Quetelet's use of it to describe *l'homme moyen*.
	Properties of the normal distribution.	Link to 2.3.	
	Standardization of normal variables.		

Topic 6—Core: Calculus

48 hours

The aim of this topic is to introduce students to the basic concepts and techniques of differential and integral calculus and their application.

	Content	Further guidance	Links
6.1	Informal ideas of limit, continuity and convergence. Definition of derivative from first principles $f'(x)=\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}$. The derivative interpreted as a gradient function and as a rate of change. Finding equations of tangents and normals. Identifying increasing and decreasing functions. The second derivative. Higher derivatives.	Include result $\lim_{\theta\to 0}\frac{\sin\theta}{\theta}=1$. Link to 1.1. Use of this definition for polynomials only. Link to binomial theorem in 1.3. Both forms of notation, $\frac{dy}{dx}$ and $f'(x)$, for the first derivative. Use of both algebra and technology. Both forms of notation, $\frac{d^2y}{dx^2}$ and $f''(x)$, for the second derivative. Familiarity with the notation $\frac{d^ny}{dx^n}$ and $f^{(n)}(x)$. Link with induction in 1.4.	**TOK:** The nature of mathematics. Does the fact that Leibniz and Newton came across the calculus at similar times support the argument that mathematics exists prior to its discovery? **Int:** How the Greeks' distrust of zero meant that Archimedes' work did not lead to calculus. **Int:** Investigate attempts by Indian mathematicians (500–1000 CE) to explain division by zero. **TOK:** Mathematics and the knower. What does the dispute between Newton and Leibniz tell us about human emotion and mathematical discovery? **Appl:** Economics HL 1.5 (theory of the firm); Chemistry SL/HL 11.3.4 (graphical techniques); Physics SL/HL 2.1 (kinematics).

	Content	Further guidance	Links
6.2	Derivatives of x^n, $\sin x$, $\cos x$, $\tan x$, e^x and $\ln x$. Differentiation of sums and multiples of functions. The product and quotient rules. The chain rule for composite functions. Related rates of change. Implicit differentiation. Derivatives of $\sec x$, $\csc x$, $\cot x$, a^x, $\log_a x$, $\arcsin x$, $\arccos x$ and $\arctan x$.		**Appl:** Physics HL 2.4 (uniform circular motion); Physics 12.1 (induced electromotive force (emf)). **TOK:** Mathematics and knowledge claims. Euler was able to make important advances in mathematical analysis before calculus had been put on a solid theoretical foundation by Cauchy and others. However, some work was not possible until after Cauchy's work. What does this tell us about the importance of proof and the nature of mathematics? **TOK:** Mathematics and the real world. The seemingly abstract concept of calculus allows us to create mathematical models that permit human feats, such as getting a man on the Moon. What does this tell us about the links between mathematical models and physical reality?
6.3	Local maximum and minimum values. Optimization problems. Points of inflexion with zero and non-zero gradients. Graphical behaviour of functions, including the relationship between the graphs of f, f' and f''. **Not required:** Points of inflexion, where $f''(x)$ is not defined, for example, $y = x^{1/3}$ at $(0,0)$.	Testing for the maximum or minimum using the change of sign of the first derivative and using the sign of the second derivative. Use of the terms "concave up" for $f''(x) > 0$, "concave down" for $f''(x) < 0$. At a point of inflexion, $f''(x) = 0$ and changes sign (concavity change).	

	Content	Further guidance	Links
6.4	Indefinite integration as anti-differentiation. Indefinite integral of x^n, $\sin x$, $\cos x$ and e^x. Other indefinite integrals using the results from 6.2. The composites of any of these with a linear function.	Indefinite integral interpreted as a family of curves. $\int \frac{1}{x} dx = \ln\|x\| + c$. Examples include $\int (2x-1)^5 dx$, $\int \frac{1}{3x+4} dx$ and $\int \frac{1}{x^2+2x+5} dx$.	
6.5	Anti-differentiation with a boundary condition to determine the constant of integration. Definite integrals. Area of the region enclosed by a curve and the x-axis or y-axis in a given interval; areas of regions enclosed by curves. Volumes of revolution about the x-axis or y-axis.	The value of some definite integrals can only be found using technology.	**Appl:** Industrial design.

	Content	Further guidance	Links
6.6	Kinematic problems involving displacement s, velocity v and acceleration a. Total distance travelled.	$v = \frac{\mathrm{d}s}{\mathrm{d}t}$, $a = \frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\mathrm{d}^2 s}{\mathrm{d}t^2} = v\frac{\mathrm{d}v}{\mathrm{d}s}$. Total distance travelled $= \int_{t_1}^{t_2} \lvert v \rvert \, \mathrm{d}t$.	**Appl:** Physics HL 2.1 (kinematics). **Int:** Does the inclusion of kinematics as core mathematics reflect a particular cultural heritage? Who decides what is mathematics?
6.7	Integration by substitution Integration by parts.	On examination papers, non-standard substitutions will be provided. Link to 6.2. Examples: $\int x \sin x \, \mathrm{d}x$ and $\int \ln x \, \mathrm{d}x$. Repeated integration by parts. Examples: $\int x^2 \mathrm{e}^x \, \mathrm{d}x$ and $\int \mathrm{e}^x \sin x \, \mathrm{d}x$.	

Topic 7—Option: Statistics and probability — 48 hours

The aims of this option are to allow students the opportunity to approach statistics in a practical way; to demonstrate a good level of statistical understanding; and to understand which situations apply and to interpret the given results. It is expected that GDCs will be used throughout this option, and that the minimum requirement of a GDC will be to find probability distribution function (pdf), cumulative distribution function (cdf), inverse cumulative distribution function, *p*-values and test statistics, including calculations for the following distributions: binomial, Poisson, normal and *t*. Students are expected to set up the problem mathematically and then read the answers from the GDC, indicating this within their written answers. Calculator-specific or brand-specific language should not be used within these explanations.

	Content	Further guidance	Links
7.1	Cumulative distribution functions for both discrete and continuous distributions.		
	Geometric distribution.		
	Negative binomial distribution.	$G(t) = \mathrm{E}(t^X) = \sum_x P(X = x)t^x$.	**Int:** Also known as Pascal's distribution.
	Probability generating functions for discrete random variables.		
	Using probability generating functions to find mean, variance and the distribution of the sum of n independent random variables.		**Aim 8:** Statistical compression of data files.
7.2	Linear transformation of a single random variable.	$\mathrm{E}(aX + b) = a\mathrm{E}(X) + b$,	
	Mean of linear combinations of n random variables.	$\mathrm{Var}(aX + b) = a^2 \mathrm{Var}(X)$.	
	Variance of linear combinations of n independent random variables.		
	Expectation of the product of independent random variables.	$\mathrm{E}(XY) = \mathrm{E}(X)\mathrm{E}(Y)$.	

	Content	Further guidance	Links
7.3	Unbiased estimators and estimates. Comparison of unbiased estimators based on variances. $\overline{X}$ as an unbiased estimator for μ. S^2 as an unbiased estimator for σ^2.	T is an unbiased estimator for the parameter θ if $\mathrm{E}(T) = \theta$. T_1 is a more efficient estimator than T_2 if $\mathrm{Var}(T_1) < \mathrm{Var}(T_2)$. $\overline{X} = \sum_{i=1}^{n} \frac{X_i}{n}$. $S^2 = \sum_{i=1}^{n} \frac{\left(X_i - \overline{X}\right)^2}{n-1}$.	**TOK**: Mathematics and the world. In the absence of knowing the value of a parameter, will an unbiased estimator always be better than a biased one?
7.4	A linear combination of independent normal random variables is normally distributed. In particular, $X \sim \mathrm{N}(\mu, \sigma^2) \Rightarrow \overline{X} \sim \mathrm{N}\left(\mu, \frac{\sigma^2}{n}\right)$. The central limit theorem.		**Aim 8/TOK:** Mathematics and the world. “Without the central limit theorem, there could be no statistics of any value within the human sciences.” **TOK:** Nature of mathematics. The central limit theorem can be proved mathematically (formalism), but its truth can be confirmed by its applications (empiricism).

	Content	Further guidance	Links
7.5	Confidence intervals for the mean of a normal population.	Use of the normal distribution when σ is known and use of the *t*-distribution when σ is unknown, regardless of sample size. The case of matched pairs is to be treated as an example of a single sample technique.	**TOK:** Mathematics and the world. Claiming brand A is “better” on average than brand B can mean very little if there is a large overlap between the confidence intervals of the two means. **Appl:** Geography.
7.6	Null and alternative hypotheses, H_0 and H_1. Significance level. Critical regions, critical values, *p*-values, one-tailed and two-tailed tests. Type I and II errors, including calculations of their probabilities. Testing hypotheses for the mean of a normal population.	Use of the normal distribution when σ is known and use of the t-distribution when σ is unknown, regardless of sample size. The case of matched pairs is to be treated as an example of a single sample technique.	**TOK:** Mathematics and the world. In practical terms, is saying that a result is significant the same as saying that it is true? **TOK:** Mathematics and the world. Does the ability to test only certain parameters in a population affect the way knowledge claims in the human sciences are valued? **Appl:** When is it more important not to make a Type I error and when is it more important not to make a Type II error?

	Content	Further guidance	Links
7.7	Introduction to bivariate distributions.	Informal discussion of commonly occurring situations, eg marks in pure mathematics and statistics exams taken by a class of students, salary and age of teachers in a certain school. The need for a measure of association between the variables and the possibility of predicting the value of one of the variables given the value of the other variable.	**Appl:** Geographic skills. **Aim 8:** The correlation between smoking and lung cancer was "discovered" using mathematics. Science had to justify the cause.
	Covariance and (population) product moment correlation coefficient ρ.	$\text{Cov}(X,Y) = \text{E}[(X-\mu_x)(Y-\mu_y)]$ $= \text{E}(XY) - \mu_x\mu_y$, where $\mu_x = \text{E}(X),\ \mu_y = \text{E}(Y)$. $\rho = \dfrac{\text{Cov}(X,Y)}{\sqrt{\text{Var}(X)\text{Var}(Y)}}$.	**Appl:** Using technology to fit a range of curves to a set of data.
	Proof that $\rho = 0$ in the case of independence and ± 1 in the case of a linear relationship between X and Y.	The use of ρ as a measure of association between X and Y, with values near 0 indicating a weak association and values near +1 or near –1 indicating a strong association.	**TOK:** Mathematics and the world. Given that a set of data may be approximately fitted by a range of curves, where would we seek for knowledge of which equation is the "true" model?
	Definition of the (sample) product moment correlation coefficient R in terms of n paired observations on X and Y. Its application to the estimation of ρ.	$R = \dfrac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2\sum_{i=1}^{n}(Y_i-\bar{Y})^2}}$ $= \dfrac{\sum_{i=1}^{n}X_iY_i - n\bar{X}\bar{Y}}{\sqrt{\left(\sum_{i=1}^{n}X_i^2 - n\bar{X}^2\right)\left(\sum Y_i^2 - n\bar{Y}^2\right)}}$.	**Aim 8:** The physicist Frank Oppenheimer wrote: "Prediction is dependent only on the assumption that observed patterns will be repeated." This is the danger of extrapolation. There are many examples of its failure in the past, eg share prices, the spread of disease, climate change.

(continued)

	Content	Further guidance	Links
	Informal interpretation of r, the observed value of R. Scatter diagrams.	Values of r near 0 indicate a weak association between X and Y, and values near ± 1 indicate a strong association.	*(see notes above)*
	The following topics are based on the assumption of bivariate normality.	It is expected that the GDC will be used wherever possible in the following work.	
	Use of the t-statistic to test the null hypothesis $\rho = 0$.	$R\sqrt{\frac{n-2}{1-R^2}}$ has the student's t-distribution with $(n-2)$ degrees of freedom.	
	Knowledge of the facts that the regression of X on Y $\left(\mathrm{E}(X \mid Y = y)\right)$ and Y on X $\left(\mathrm{E}(Y \mid X = x)\right)$ are linear. Least-squares estimates of these regression lines (proof not required). The use of these regression lines to predict the value of one of the variables given the value of the other.	$x - \bar{x} = \left(\frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(y_i - \bar{y})^2}\right)(y - \bar{y})$ $= \left(\frac{\sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{\sum_{i=1}^{n} y_i^2 - n\bar{y}^2}\right)(y - \bar{y}),$ $y - \bar{y} = \left(\frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)(x - \bar{x})$ $= \left(\frac{\sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{\sum_{i=1}^{n} x_i^2 - n\bar{x}^2}\right)(x - \bar{x}).$	

Topic 8—Option: Sets, relations and groups — 48 hours

The aims of this option are to provide the opportunity to study some important mathematical concepts, and introduce the principles of proof through abstract algebra.

	Content	Further guidance	Links
8.1	Finite and infinite sets. Subsets. Operations on sets: union; intersection; complement; set difference; symmetric difference.		**TOK:** Cantor theory of transfinite numbers, Russell's paradox, Godel's incompleteness theorems.
	De Morgan's laws: distributive, associative and commutative laws (for union and intersection).	Illustration of these laws using Venn diagrams. Students may be asked to prove that two sets are the same by establishing that $A \subseteq B$ and $B \subseteq A$.	**Appl:** Logic, Boolean algebra, computer circuits.
8.2	Ordered pairs: the Cartesian product of two sets.		
	Relations: equivalence relations; equivalence classes.	An equivalence relation on a set forms a partition of the set.	**Appl**, **Int:** Scottish clans.
8.3	Functions: injections; surjections; bijections.	The term codomain.	
	Composition of functions and inverse functions.	Knowledge that the function composition is not a commutative operation and that if f is a bijection from set A to set B then f^{-1} exists and is a bijection from set B to set A.	

	Content	Further guidance	Links
8.4	Binary operations. Operation tables (Cayley tables).	A binary operation $*$ on a non-empty set S is a rule for combining any two elements $a, b \in S$ to give a unique element c. That is, in this definition, a binary operation on a set is not necessarily closed.	
8.5	Binary operations: associative, distributive and commutative properties.	The arithmetic operations on $\mathbb{R}$ and $\mathbb{C}$. Examples of distributivity could include the fact that, on $\mathbb{R}$, multiplication is distributive over addition but addition is not distributive over multiplication.	**TOK:** Which are more fundamental, the general models or the familiar examples?
8.6	The identity element e. The inverse a^{-1} of an element a. Proof that left-cancellation and right-cancellation by an element a hold, provided that a has an inverse. Proofs of the uniqueness of the identity and inverse elements.	Both the right-identity $a * e = a$ and left-identity $e * a = a$ must hold if e is an identity element. Both $a * a^{-1} = e$ and $a^{-1} * a = e$ must hold.	

	Content	Further guidance	Links
8.7	The definition of a group $\{G, *\}$. The operation table of a group is a Latin square, but the converse is false.	For the set G under a given operation $*$: • G is closed under $*$; • $*$ is associative; • G contains an identity element; • each element in G has an inverse in G.	**Appl:** Existence of formula for roots of polynomials. **Appl:** Galois theory for the impossibility of such formulae for polynomials of degree 5 or higher.
	Abelian groups.	$a*b = b*a$, for all $a, b \in G$.	
8.8	Examples of groups: • $\mathbb{R}$, $\mathbb{Q}$, $\mathbb{Z}$ and $\mathbb{C}$ under addition; • integers under addition modulo *n*; • non-zero integers under multiplication, modulo *p*, where *p* is prime;		**Appl:** Rubik's cube, time measures, crystal structure, symmetries of molecules, strut and cable constructions, Physics H2.2 (special relativity), the 8–fold way, supersymmetry.
	symmetries of plane figures, including equilateral triangles and rectangles; invertible functions under composition of functions.	The composition $T_2 \circ T_1$ denotes T_1 followed by T_2.	
8.9	The order of a group. The order of a group element. Cyclic groups. Generators. Proof that all cyclic groups are Abelian.		**Appl:** Music circle of fifths, prime numbers.

	Content	Further guidance	Links
8.10	Permutations under composition of permutations. Cycle notation for permutations. Result that every permutation can be written as a composition of disjoint cycles. The order of a combination of cycles.	On examination papers: the form $p=\begin{pmatrix}1 & 2 & 3\\ 3 & 1 & 2\end{pmatrix}$ or in cycle notation (132) will be used to represent the permutation $1\to 3$, $2\to 1$, $3\to 2$.	**Appl:** Cryptography, campanology.
8.11	Subgroups, proper subgroups.	A proper subgroup is neither the group itself nor the subgroup containing only the identity element.	
	Use and proof of subgroup tests.	Suppose that $\{G,*\}$ is a group and H is a non-empty subset of G. Then $\{H,*\}$ is a subgroup of $\{G,*\}$ if $a*b^{-1}\in H$ whenever $a,b\in H$. Suppose that $\{G,*\}$ is a finite group and H is a non-empty subset of G. Then $\{H,*\}$ is a subgroup of $\{G,*\}$ if H is closed under $*$.	
	Definition and examples of left and right cosets of a subgroup of a group.		
	Lagrange's theorem.		**Appl:** Prime factorization, symmetry breaking.
	Use and proof of the result that the order of a finite group is divisible by the order of any element. (Corollary to Lagrange's theorem.)		

	Content	Further guidance	Links
8.12	Definition of a group homomorphism.	Infinite groups as well as finite groups. Let $\{G, *\}$ and $\{H, \circ\}$ be groups, then the function $f: G \to H$ is a homomorphism if $f(a * b) = f(a) \circ f(b)$ for all $a, b \in G$.	
	Definition of the kernel of a homomorphism. Proof that the kernel and range of a homomorphism are subgroups.	If $f: G \to H$ is a group homomorphism, then $\mathrm{Ker}(f)$ is the set of $a \in G$ such that $f(a) = e_H$.	
	Proof of homomorphism properties for identities and inverses.	Identity: let e_G and e_H be the identity elements of $\{G, *\}$ and $\{H, \circ\}$, respectively, then $f(e_G) = e_H$. Inverse: $f(a^{-1}) = \left(f(a)\right)^{-1}$ for all $a \in G$.	
	Isomorphism of groups.	Infinite groups as well as finite groups. The homomorphism $f: G \to H$ is an isomorphism if *f* is bijective.	
	The order of an element is unchanged by an isomorphism.		

Topic 9—Option: Calculus

48 hours

The aims of this option are to introduce limit theorems and convergence of series, and to use calculus results to solve differential equations.

9.1	Infinite sequences of real numbers and their convergence or divergence.	Informal treatment of limit of sum, difference, product, quotient; squeeze theorem. Divergent is taken to mean not convergent.	**TOK:** Zeno's paradox, impact of infinite sequences and limits on our understanding of the physical world.
9.2	Convergence of infinite series. Tests for convergence: comparison test; limit comparison test; ratio test; integral test.	The sum of a series is the limit of the sequence of its partial sums. Students should be aware that if $\lim_{n\to\infty} x_n = 0$ then the series is not necessarily convergent, but if $\lim_{n\to\infty} x_n \neq 0$, the series diverges.	**TOK:** Euler's idea that $1-1+1-1+\quad=\frac{1}{2}$. Was it a mistake or just an alternative view?
	The p-series, $\sum \frac{1}{n^p}$.	$\sum \frac{1}{n^p}$ is convergent for $p>1$ and divergent otherwise. When $p=1$, this is the harmonic series.	
	Series that converge absolutely. Series that converge conditionally.	Conditions for convergence.	
	Alternating series. Power series: radius of convergence and interval of convergence. Determination of the radius of convergence by the ratio test.	The absolute value of the truncation error is less than the next term in the series.	

	Content	Further guidance	Links
9.3	Continuity and differentiability of a function at a point. Continuous functions and differentiable functions.	Test for continuity: $\lim_{x \to a-} f(x) = f(a) = \lim_{x \to a+} f(x)$. Test for differentiability: f is continuous at a and $\lim_{h \to 0-} \frac{f(a+h) - f(a)}{h}$ and $\lim_{h \to 0+} \frac{f(a+h) - f(a)}{h}$ exist and are equal. Students should be aware that a function may be continuous but not differentiable at a point, eg $f(x) = \lvert x \rvert$ and simple piecewise functions.	
9.4	The integral as a limit of a sum; lower and upper Riemann sums. Fundamental theorem of calculus. Improper integrals of the type $\int_a^\infty f(x)\,dx$.	 $\frac{d}{dx}\left[\int_a^x f(y)\,dy\right] = f(x)$.	**Int:** How close was Archimedes to integral calculus? **Int:** Contribution of Arab, Chinese and Indian mathematicians to the development of calculus. **Aim 8:** Leibniz versus Newton versus the “giants” on whose shoulders they stood—who deserves credit for mathematical progress? **TOK:** Consider $f(x) = \frac{1}{x}$, $1 \le x \le \infty$. An infinite area sweeps out a finite volume. Can this be reconciled with our intuition? What does this tell us about mathematical knowledge?

	Content	Further guidance	Links
9.5	First-order differential equations. Geometric interpretation using slope fields, including identification of isoclines. Numerical solution of $\frac{dy}{dx} = f(x, y)$ using Euler's method. Variables separable. Homogeneous differential equation $\frac{dy}{dx} = f\left(\frac{y}{x}\right)$ using the substitution $y = vx$. Solution of $y' + P(x)y = Q(x)$, using the integrating factor.	$y_{n+1} = y_n + hf(x_n, y_n)$, $x_{n+1} = x_n + h$, where h is a constant.	**Appl:** Real-life differential equations, eg Newton's law of cooling, population growth, carbon dating.
9.6	Rolle's theorem. Mean value theorem. Taylor polynomials; the Lagrange form of the error term. Maclaurin series for e^x, $\sin x$, $\cos x$, $\ln(1+x)$, $(1+x)^p$, $p \in \mathbb{Q}$. Use of substitution, products, integration and differentiation to obtain other series. Taylor series developed from differential equations.	Applications to the approximation of functions; formula for the error term, in terms of the value of the $(n+1)^{\text{th}}$ derivative at an intermediate point. Students should be aware of the intervals of convergence.	**Int, TOK:** Influence of Bourbaki on understanding and teaching of mathematics. **Int:** Compare with work of the Kerala school.

	Content	Further guidance	Links
9.7	The evaluation of limits of the form $\lim\limits_{x\to a}\frac{f(x)}{g(x)}$ and $\lim\limits_{x\to\infty}\frac{f(x)}{g(x)}$. Using l'Hôpital's rule or the Taylor series.	The indeterminate forms $\frac{0}{0}$ and $\frac{\infty}{\infty}$. Repeated use of l'Hôpital's rule.	

Topic 10—Option: Discrete mathematics — 48 hours

The aim of this option is to provide the opportunity for students to engage in logical reasoning, algorithmic thinking and applications.

	Content	Further guidance	Links
10.1	Strong induction. Pigeon-hole principle.	For example, proofs of the fundamental theorem of arithmetic and the fact that a tree with n vertices has $n-1$ edges.	**TOK:** Mathematics and knowledge claims. The difference between proof and conjecture, eg Goldbach's conjecture. Can a mathematical statement be true before it is proven? **TOK:** Proof by contradiction.
10.2	$a \mid b \Rightarrow b = na$ for some $n \in \mathbb{Z}$.		
	The theorem $a \mid b$ and $a \mid c \Rightarrow a \mid (bx \pm cy)$ where $x, y \in \mathbb{Z}$.	The division algorithm $a = bq + r$, $0 \le r < b$.	
	Division and Euclidean algorithms. The greatest common divisor, $\gcd(a,b)$, and the least common multiple, $\text{lcm}(a,b)$, of integers a and b. Prime numbers; relatively prime numbers and the fundamental theorem of arithmetic.	The Euclidean algorithm for determining the greatest common divisor of two integers.	**Int:** Euclidean algorithm contained in Euclid's *Elements*, written in Alexandria about 300 BCE. **Aim 8:** Use of prime numbers in cryptography. The possible impact of the discovery of powerful factorization techniques on internet and bank security.
10.3	Linear Diophantine equations $ax + by = c$.	General solutions required and solutions subject to constraints. For example, all solutions must be positive.	**Int:** Described in Diophantus' *Arithmetica* written in Alexandria in the 3rd century CE. When studying *Arithmetica*, a French mathematician, Pierre de Fermat (1601–1665) wrote in the margin that he had discovered a simple proof regarding higher-order Diophantine equations—Fermat's last theorem.

	Content	Further guidance	Links
10.4	Modular arithmetic. The solution of linear congruences. Solution of simultaneous linear congruences (Chinese remainder theorem).		**Int:** Discussed by Chinese mathematician Sun Tzu in the 3rd century CE.
10.5	Representation of integers in different bases.	On examination papers, questions that go beyond base 16 will not be set.	**Int:** Babylonians developed a base 60 number system and the Mayans a base 20 number system.
10.6	Fermat's little theorem.	$a^p = a \pmod{p}$, where p is prime.	**TOK:** Nature of mathematics. An interest may be pursued for centuries before becoming "useful".

	Content	Further guidance	Links
10.7	Graphs, vertices, edges, faces. Adjacent vertices, adjacent edges. Degree of a vertex, degree sequence. Handshaking lemma.	Two vertices are adjacent if they are joined by an edge. Two edges are adjacent if they have a common vertex.	**Aim 8:** Symbolic maps, eg Metro and Underground maps, structural formulae in chemistry, electrical circuits. **TOK:** Mathematics and knowledge claims. Proof of the four-colour theorem. If a theorem is proved by computer, how can we claim to know that it is true?
	Simple graphs; connected graphs; complete graphs; bipartite graphs; planar graphs; trees; weighted graphs, including tabular representation. Subgraphs; complements of graphs.	It should be stressed that a graph should not be assumed to be simple unless specifically stated. The term adjacency table may be used.	**Aim 8:** Importance of planar graphs in constructing circuit boards.
	Euler's relation: $v-e+f=2$; theorems for planar graphs including $e \le 3v-6$, $e \le 2v-4$, leading to the results that κ_5 and $\kappa_{3,3}$ are not planar.	If the graph is simple and planar and $v \ge 3$, then $e \le 3v-6$. If the graph is simple, planar, has no cycles of length 3 and $v \ge 3$, then $e \le 2v-4$.	**TOK:** Mathematics and knowledge claims. Applications of the Euler characteristic $(v-e+f)$ to higher dimensions. Its use in understanding properties of shapes that cannot be visualized.
10.8	Walks, trails, paths, circuits, cycles.		
	Eulerian trails and circuits.	A connected graph contains an Eulerian circuit if and only if every vertex of the graph is of even degree.	**Int:** The "Bridges of Königsberg" problem.
	Hamiltonian paths and cycles.	Simple treatment only.	
10.9	Graph algorithms: Kruskal's; Dijkstra's.		

	Content	Further guidance	Links
10.10	Chinese postman problem.	To determine the shortest route around a weighted graph going along each edge at least once.	**Int:** Problem posed by the Chinese mathematician Kwan Mei-Ko in 1962.
	Not required: Graphs with more than four vertices of odd degree.		
	Travelling salesman problem.	To determine the Hamiltonian cycle of least weight in a weighted complete graph.	**TOK:** Mathematics and knowledge claims. How long would it take a computer to test all Hamiltonian cycles in a complete, weighted graph with just 30 vertices?
	Nearest-neighbour algorithm for determining an upper bound.		
	Deleted vertex algorithm for determining a lower bound.		
10.11	Recurrence relations. Initial conditions, recursive definition of a sequence.		**TOK:** Mathematics and the world. The connections of sequences such as the Fibonacci sequence with art and biology.
	Solution of first- and second-degree linear homogeneous recurrence relations with constant coefficients.	Includes the cases where auxiliary equation has equal roots or complex roots.	
	The first-degree linear recurrence relation $u_n = au_{n-1} + b$.		
	Modelling with recurrence relations.	Solving problems such as compound interest, debt repayment and counting problems.	

Glossary of terminology: Discrete mathematics

Introduction

Teachers and students should be aware that many different terminologies exist in graph theory, and that different textbooks may employ different combinations of these. Examples of these are: vertex/node/junction/point; edge/route/arc; degree/order of a vertex; multiple edges/parallel edges; loop/self-loop.

In IB examination questions, the terminology used will be as it appears in the syllabus. For clarity, these terms are defined below.

Terminology

Bipartite graph	A graph whose vertices can be divided into two sets such that no two vertices in the same set are adjacent.
Circuit	A walk that begins and ends at the same vertex, and has no repeated edges.
Complement of a graph *G*	A graph with the same vertices as G but which has an edge between any two vertices if and only if G does not.
Complete bipartite graph	A bipartite graph in which every vertex in one set is joined to every vertex in the other set.
Complete graph	A simple graph in which each pair of vertices is joined by an edge.
Connected graph	A graph in which each pair of vertices is joined by a path.
Cycle	A walk that begins and ends at the same vertex, and has no other repeated vertices.
Degree of a vertex	The number of edges joined to the vertex; a loop contributes two edges, one for each of its end points.
Disconnected graph	A graph that has at least one pair of vertices not joined by a path.
Eulerian circuit	A circuit that contains every edge of a graph.
Eulerian trail	A trail that contains every edge of a graph.
Graph	Consists of a set of vertices and a set of edges.
Graph isomorphism between two simple graphs *G* and *H*	A one-to-one correspondence between vertices of G and H such that a pair of vertices in G is adjacent if and only if the corresponding pair in H is adjacent.
Hamiltonian cycle	A cycle that contains all the vertices of the graph.
Hamiltonian path	A path that contains all the vertices of the graph.
Loop	An edge joining a vertex to itself.

Minimum spanning tree	A spanning tree of a weighted graph that has the minimum total weight.
Multiple edges	Occur if more than one edge joins the same pair of vertices.
Path	A walk with no repeated vertices.
Planar graph	A graph that can be drawn in the plane without any edge crossing another.
Simple graph	A graph without loops or multiple edges.
Spanning tree of a graph	A subgraph that is a tree, containing every vertex of the graph.
Subgraph	A graph within a graph.
Trail	A walk in which no edge appears more than once.
Tree	A connected graph that contains no cycles.
Walk	A sequence of linked edges.
Weighted graph	A graph in which each edge is allocated a number or weight.
Weighted tree	A tree in which each edge is allocated a number or weight.

Assessment in the Diploma Programme

General

Assessment is an integral part of teaching and learning. The most important aims of assessment in the Diploma Programme are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessment are used in the Diploma Programme. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- Formative assessment informs both teaching and learning. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.
- Summative assessment gives an overview of previous learning and is concerned with measuring student achievement.

The Diploma Programme primarily focuses on summative assessment designed to record student achievement at or towards the end of the course of study. However, many of the assessment instruments can also be used formatively during the course of teaching and learning, and teachers are encouraged to do this. A comprehensive assessment plan is viewed as being integral with teaching, learning and course organization. For further information, see the IB *Programme standards and practices* document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the Diploma Programme, please refer to the publication *Diploma Programme assessment: Principles and practice*.

To support teachers in the planning, delivery and assessment of the Diploma Programme courses, a variety of resources can be found on the OCC or purchased from the IB store (http://store.ibo.org). Teacher support materials, subject reports, internal assessment guidance, grade descriptors, as well as resources from other teachers, can be found on the OCC. Specimen and past examination papers as well as markschemes can be purchased from the IB store.

Methods of assessment

The IB uses several methods to assess work produced by students.

Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do, and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses. Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

Markschemes

This generic term is used to describe analytic markschemes that are prepared for specific examination papers. Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from the students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response. A markscheme may include the content expected in the responses to questions or may be a series of marking notes giving guidance on how to apply criteria.

Assessment outline

First examinations 2014

Assessment component	Weighting
External assessment (5 hours)	**80%**
Paper 1 (2 hours) No calculator allowed. (100 marks) *Section A* Compulsory short-response questions based on the core syllabus. *Section B* Compulsory extended-response questions based on the core syllabus.	**30%**
Paper 2 (2 hours) Graphic display calculator required. (100 marks) *Section A* Compulsory short-response questions based on the core syllabus. *Section B* Compulsory extended-response questions based on the core syllabus.	**30%**
Paper 3 (1 hour) Graphic display calculator required. (50 marks) Compulsory extended-response questions based mainly on the syllabus options.	**20%**
Internal assessment This component is internally assessed by the teacher and externally moderated by the IB at the end of the course. **Mathematical exploration** Internal assessment in mathematics HL is an individual exploration. This is a piece of written work that involves investigating an area of mathematics. (20 marks)	**20%**

External assessment

General

Markschemes are used to assess students in all papers. The markschemes are specific to each examination.

External assessment details

Papers 1, 2 and 3

These papers are externally set and externally marked. Together, they contribute 80% of the final mark for the course. These papers are designed to allow students to demonstrate what they know and what they can do.

Calculators

Paper 1

Students are not permitted access to any calculator. Questions will mainly involve analytic approaches to solutions, rather than requiring the use of a GDC. The paper is not intended to require complicated calculations, with the potential for careless errors. However, questions will include some arithmetical manipulations when they are essential to the development of the question.

Papers 2 and 3

Students must have access to a GDC at all times. However, not all questions will necessarily require the use of the GDC. Regulations covering the types of GDC allowed are provided in the *Handbook of procedures for the Diploma Programme*.

Mathematics HL and further mathematics HL formula booklet

Each student must have access to a clean copy of the formula booklet during the examination. It is the responsibility of the school to download a copy from IBIS or the OCC and to ensure that there are sufficient copies available for all students.

Awarding of marks

Marks may be awarded for method, accuracy, answers and reasoning, including interpretation.

In paper 1 and paper 2, full marks are not necessarily awarded for a correct answer with no working. Answers must be supported by working and/or explanations (in the form of, for example, diagrams, graphs or calculations). Where an answer is incorrect, some marks may be given for correct method, provided this is shown by written working. All students should therefore be advised to show their working.

Paper 1

Duration: 2 hours
Weighting: 30%

- This paper consists of section A, short-response questions, and section B, extended-response questions.
- Students are not permitted access to any calculator on this paper.

Syllabus coverage

- Knowledge of **all** core topics is required for this paper. However, not all topics are necessarily assessed in every examination session.

Mark allocation

- This paper is worth **100** marks, representing **30%** of the final mark.
- Questions of varying levels of difficulty and length are set. Therefore, individual questions may not necessarily each be worth the same number of marks. The exact number of marks allocated to each question is indicated at the start of the question.

Section A

- This section consists of compulsory short-response questions based on the core syllabus. It is worth 50 marks.
- The intention of this section is to test students' knowledge and understanding across the breadth of the syllabus. However, it should not be assumed that the separate topics are given equal emphasis.

Question type

- A small number of steps is needed to solve each question.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.

Section B

- This section consists of a small number of compulsory extended-response questions based on the core syllabus. It is worth 50 marks.
- Individual questions may require knowledge of more than one topic.
- The intention of this section is to test students' knowledge and understanding of the core in depth. The range of syllabus topics tested in this section may be narrower than that tested in section A.

Question type

- Questions require extended responses involving sustained reasoning.
- Individual questions will develop a single theme.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.
- Normally, each question reflects an incline of difficulty, from relatively easy tasks at the start of a question to relatively difficult tasks at the end of a question. The emphasis is on problem-solving.

Paper 2

Duration: 2 hours
Weighting: 30%

- This paper consists of section A, short-response questions, and section B, extended-response questions.
- A GDC is required for this paper, but not every question will necessarily require its use.

Syllabus coverage

- Knowledge of **all** core topics is required for this paper. However, not all topics are necessarily assessed in every examination session.

Mark allocation

- This paper is worth **100** marks, representing **30%** of the final mark.
- Questions of varying levels of difficulty and length are set. Therefore, individual questions may not necessarily each be worth the same number of marks. The exact number of marks allocated to each question is indicated at the start of the question.

Section A

- This section consists of compulsory short-response questions based on the core syllabus. It is worth 50 marks.
- The intention of this section is to test students' knowledge and understanding across the breadth of the syllabus. However, it should not be assumed that the separate topics are given equal emphasis.

Question type

- A small number of steps is needed to solve each question.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.

Section B

- This section consists of a small number of compulsory extended-response questions based on the core syllabus. It is worth 50 marks.
- Individual questions may require knowledge of more than one topic.
- The intention of this section is to test students' knowledge and understanding of the core in depth. The range of syllabus topics tested in this section may be narrower than that tested in section A.

Question type

- Questions require extended responses involving sustained reasoning.
- Individual questions will develop a single theme.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.
- Normally, each question reflects an incline of difficulty, from relatively easy tasks at the start of a question to relatively difficult tasks at the end of a question. The emphasis is on problem-solving.

Paper 3

Duration: 1 hour
Weighting: 20%

- This paper consists of a small number of compulsory extended-response questions based on the option chosen.
- Where possible, the first part of each question will be on core material leading to the option topic. When this is not readily achievable, as, for example, with the discrete mathematics option, the level of difficulty of the earlier part of a question will be comparable to that of the core questions.

Syllabus coverage

- Students must answer **all** questions.
- Knowledge of the entire content of the option studied, as well as the core material, is required for this paper.

Mark allocation

- This paper is worth **50** marks, representing **20%** of the final mark.
- Questions may be unequal in terms of length and level of difficulty. Therefore, individual questions may not be worth the same number of marks. The exact number of marks allocated to each question is indicated at the start of each question.

Question type

- Questions require extended responses involving sustained reasoning.
- Individual questions will develop a single theme or be divided into unconnected parts. Where the latter occur, the unconnected parts will be clearly labelled as such.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.
- Normally, each question reflects an incline of difficulty, from relatively easy tasks at the start of a question to relatively difficult tasks at the end of a question. The emphasis is on problem-solving.

Internal assessment

Purpose of internal assessment

Internal assessment is an integral part of the course and is compulsory for all students. It enables students to demonstrate the application of their skills and knowledge, and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught.

Internal assessment in mathematics HL is an individual exploration. This is a piece of written work that involves investigating an area of mathematics. It is marked according to five assessment criteria.

Guidance and authenticity

The exploration submitted for internal assessment must be the student's own work. However, it is not the intention that students should decide upon a title or topic and be left to work on the exploration without any further support from the teacher. The teacher should play an important role during both the planning stage and the period when the student is working on the exploration. It is the responsibility of the teacher to ensure that students are familiar with:

- the requirements of the type of work to be internally assessed
- the IB academic honesty policy available on the OCC
- the assessment criteria—students must understand that the work submitted for assessment must address these criteria effectively.

Teachers and students must discuss the exploration. Students should be encouraged to initiate discussions with the teacher to obtain advice and information, and students must not be penalized for seeking guidance. However, if a student could not have completed the exploration without substantial support from the teacher, this should be recorded on the appropriate form from the *Handbook of procedures for the Diploma Programme*.

It is the responsibility of teachers to ensure that all students understand the basic meaning and significance of concepts that relate to academic honesty, especially authenticity and intellectual property. Teachers must ensure that all student work for assessment is prepared according to the requirements and must explain clearly to students that the exploration must be entirely their own.

As part of the learning process, teachers can give advice to students on a **first draft** of the exploration. This advice should be in terms of the way the work could be improved, but this first draft must not be heavily annotated or edited by the teacher. The next version handed to the teacher after the first draft must be the final one.

All work submitted to the IB for moderation or assessment must be authenticated by a teacher, and must not include any known instances of suspected or confirmed malpractice. Each student must sign the coversheet for internal assessment to confirm that the work is his or her authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work to a teacher (or the coordinator) for internal assessment, together with the signed coversheet, it cannot be retracted.

Authenticity may be checked by discussion with the student on the content of the work, and scrutiny of one or more of the following:

- the student's initial proposal
- the first draft of the written work
- the references cited
- the style of writing compared with work known to be that of the student.

The requirement for teachers and students to sign the coversheet for internal assessment applies to the work of all students, not just the sample work that will be submitted to an examiner for the purpose of moderation. If the teacher and student sign a coversheet, but there is a comment to the effect that the work may not be authentic, the student will not be eligible for a mark in that component and no grade will be awarded. For further details refer to the IB publication *Academic honesty* and the relevant articles in the *General regulations: Diploma Programme*.

The same piece of work cannot be submitted to meet the requirements of both the internal assessment and the extended essay.

Group work

Group work should not be used for explorations. Each exploration is an individual piece of work based on different data collected or measurements generated.

It should be made clear to students that all work connected with the exploration, including the writing of the exploration, should be their own. It is therefore helpful if teachers try to encourage in students a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work.

Time allocation

Internal assessment is an integral part of the mathematics HL course, contributing 20% to the final assessment in the course. This weighting should be reflected in the time that is allocated to teaching the knowledge, skills and understanding required to undertake the work as well as the total time allocated to carry out the work.

It is expected that a total of approximately 10 teaching hours should be allocated to the work. This should include:

- time for the teacher to explain to students the requirements of the exploration
- class time for students to work on the exploration
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

Using assessment criteria for internal assessment

For internal assessment, a number of assessment criteria have been identified. Each assessment criterion has level descriptors describing specific levels of achievement together with an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Teachers must judge the internally assessed work against the criteria using the level descriptors.

- The aim is to find, for each criterion, the descriptor that conveys most accurately the level attained by the student.
- When assessing a student's work, teachers should read the level descriptors for each criterion, starting with level 0, until they reach a descriptor that describes a level of achievement that has not been reached. The level of achievement gained by the student is therefore the preceding one, and it is this that should be recorded.
- Only whole numbers should be recorded; partial marks, that is fractions and decimals, are not acceptable.
- Teachers should not think in terms of a pass or fail boundary, but should concentrate on identifying the appropriate descriptor for each assessment criterion.
- The highest level descriptors do not imply faultless performance but should be achievable by a student. Teachers should not hesitate to use the extremes if they are appropriate descriptions of the work being assessed.
- A student who attains a high level of achievement in relation to one criterion will not necessarily attain high levels of achievement in relation to the other criteria. Similarly, a student who attains a low level of achievement for one criterion will not necessarily attain low achievement levels for the other criteria. Teachers should not assume that the overall assessment of the students will produce any particular distribution of marks.
- It is expected that the assessment criteria be made available to students.

Internal assessment details

Mathematical exploration

Duration: 10 teaching hours

Weighting: 20%

Introduction

The internally assessed component in this course is a mathematical exploration. This is a short report written by the student based on a topic chosen by him or her, and it should focus on the mathematics of that particular area. The emphasis is on mathematical communication (including formulae, diagrams, graphs and so on), with accompanying commentary, good mathematical writing and thoughtful reflection. A student should develop his or her own focus, with the teacher providing feedback via, for example, discussion and interview. This will allow the students to develop areas of interest to them without a time constraint as in an examination, and allow all students to experience a feeling of success.

The final report should be approximately 6 to 12 pages long. It can be either word processed or handwritten. Students should be able to explain all stages of their work in such a way that demonstrates clear understanding. While there is no requirement that students present their work in class, it should be written in such a way that their peers would be able to follow it fairly easily. The report should include a detailed bibliography, and sources need to be referenced in line with the IB academic honesty policy. Direct quotes must be acknowledged.

The purpose of the exploration

The aims of the mathematics HL course are carried through into the objectives that are formally assessed as part of the course, through either written examination papers, or the exploration, or both. In addition to testing the objectives of the course, the exploration is intended to provide students with opportunities to increase their understanding of mathematical concepts and processes, and to develop a wider appreciation of mathematics. These are noted in the aims of the course, **in particular, aims 6–9 (applications, technology, moral, social**

and ethical implications, and the international dimension). It is intended that, by doing the exploration, students benefit from the mathematical activities undertaken and find them both stimulating and rewarding. It will enable students to acquire the attributes of the IB learner profile.

The specific purposes of the exploration are to:

- develop students' personal insight into the nature of mathematics and to develop their ability to ask their own questions about mathematics
- provide opportunities for students to complete a piece of mathematical work over an extended period of time
- enable students to experience the satisfaction of applying mathematical processes independently
- provide students with the opportunity to experience for themselves the beauty, power and usefulness of mathematics
- encourage students, where appropriate, to discover, use and appreciate the power of technology as a mathematical tool
- enable students to develop the qualities of patience and persistence, and to reflect on the significance of their work
- provide opportunities for students to show, with confidence, how they have developed mathematically.

Management of the exploration

Work for the exploration should be incorporated into the course so that students are given the opportunity to learn the skills needed. Time in class can therefore be used for general discussion of areas of study, as well as familiarizing students with the criteria. Further details on the development of the exploration are included in the teacher support material.

Requirements and recommendations

Students can choose from a wide variety of activities, for example, modelling, investigations and applications of mathematics. To assist teachers and students in the choice of a topic, a list of stimuli is available in the teacher support material. However, students are not restricted to this list.

The exploration should not normally exceed 12 pages, including diagrams and graphs, but excluding the bibliography. However, it is the quality of the mathematical writing that is important, not the length.

The teacher is expected to give appropriate guidance at all stages of the exploration by, for example, directing students into more productive routes of inquiry, making suggestions for suitable sources of information, and providing advice on the content and clarity of the exploration in the writing-up stage.

Teachers are responsible for indicating to students the existence of errors but should not explicitly correct these errors. It must be emphasized that students are expected to consult the teacher throughout the process.

All students should be familiar with the requirements of the exploration and the criteria by which it is assessed. Students need to start planning their explorations as early as possible in the course. Deadlines should be firmly established. There should be a date for submission of the exploration topic and a brief outline description, a date for the submission of the first draft and, of course, a date for completion.

In developing their explorations, students should aim to make use of mathematics learned as part of the course. The mathematics used should be commensurate with the level of the course, that is, it should be similar to that suggested by the syllabus. It is not expected that students produce work that is outside the mathematics HL syllabus—however, this is not penalized.

Internal assessment criteria

The exploration is internally assessed by the teacher and externally moderated by the IB using assessment criteria that relate to the objectives for mathematics HL.

Each exploration is assessed against the following five criteria. The final mark for each exploration is the sum of the scores for each criterion. The maximum possible final mark is 20.

Students will not receive a grade for mathematics HL if they have not submitted an exploration.

Criterion A	Communication
Criterion B	Mathematical presentation
Criterion C	Personal engagement
Criterion D	Reflection
Criterion E	Use of mathematics

Criterion A: Communication

This criterion assesses the organization and coherence of the exploration. A well-organized exploration includes an introduction, has a rationale (which includes explaining why this topic was chosen), describes the aim of the exploration and has a conclusion. A coherent exploration is logically developed and easy to follow.

Graphs, tables and diagrams should accompany the work in the appropriate place and not be attached as appendices to the document.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	The exploration has some coherence.
2	The exploration has some coherence and shows some organization.
3	The exploration is coherent and well organized.
4	The exploration is coherent, well organized, concise and complete.

Criterion B: Mathematical presentation

This criterion assesses to what extent the student is able to:

- use appropriate mathematical language (notation, symbols, terminology)
- define key terms, where required
- use multiple forms of mathematical representation, such as formulae, diagrams, tables, charts, graphs and models, where appropriate.

Students are expected to use mathematical language when communicating mathematical ideas, reasoning and findings.

Students are encouraged to choose and use appropriate ICT tools such as graphic display calculators, screenshots, graphing, spreadsheets, databases, drawing and word-processing software, as appropriate, to enhance mathematical communication.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	There is some appropriate mathematical presentation.
2	The mathematical presentation is mostly appropriate.
3	The mathematical presentation is appropriate throughout.

Criterion C: Personal engagement

This criterion assesses the extent to which the student engages with the exploration and makes it their own. Personal engagement may be recognized in different attributes and skills. These include thinking independently and/or creatively, addressing personal interest and presenting mathematical ideas in their own way.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	There is evidence of limited or superficial personal engagement.
2	There is evidence of some personal engagement.
3	There is evidence of significant personal engagement.
4	There is abundant evidence of outstanding personal engagement.

Criterion D: Reflection

This criterion assesses how the student reviews, analyses and evaluates the exploration. Although reflection may be seen in the conclusion to the exploration, it may also be found throughout the exploration.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	There is evidence of limited or superficial reflection.
2	There is evidence of meaningful reflection.
3	There is substantial evidence of critical reflection.

Criterion E: Use of mathematics

This criterion assesses to what extent and how well students use mathematics in the exploration.

Students are expected to produce work that is commensurate with the level of the course. The mathematics explored should either be part of the syllabus, or at a similar level or beyond. It should not be completely based on mathematics listed in the prior learning. If the level of mathematics is not commensurate with the level of the course, a maximum of two marks can be awarded for this criterion.

The mathematics can be regarded as correct even if there are occasional minor errors as long as they do not detract from the flow of the mathematics or lead to an unreasonable outcome.

Sophistication in mathematics may include understanding and use of challenging mathematical concepts, looking at a problem from different perspectives and seeing underlying structures to link different areas of mathematics.

Rigour involves clarity of logic and language when making mathematical arguments and calculations.

Precise mathematics is error-free and uses an appropriate level of accuracy at all times.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	Some relevant mathematics is used. Limited understanding is demonstrated.
2	Some relevant mathematics is used. The mathematics explored is partially correct. Some knowledge and understanding are demonstrated.
3	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is correct. Good knowledge and understanding are demonstrated.
4	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is correct and reflects the sophistication expected. Good knowledge and understanding are demonstrated.
5	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is correct and reflects the sophistication and rigour expected. Thorough knowledge and understanding are demonstrated.
6	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is precise and reflects the sophistication and rigour expected. Thorough knowledge and understanding are demonstrated.

Glossary of command terms

Command terms with definitions

Students should be familiar with the following key terms and phrases used in examination questions, which are to be understood as described below. Although these terms will be used in examination questions, other terms may be used to direct students to present an argument in a specific way.

Calculate	Obtain a numerical answer showing the relevant stages in the working.
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of the similarities between two (or more) items or situations, referring to both (all) of them throughout.
Compare and contrast	Give an account of the similarities and differences between two (or more) items or situations, referring to both (all) of them throughout.
Construct	Display information in a diagrammatic or logical form.
Contrast	Give an account of the differences between two (or more) items or situations, referring to both (all) of them throughout.
Deduce	Reach a conclusion from the information given.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
Describe	Give a detailed account.
Determine	Obtain the only possible answer.
Differentiate	Obtain the derivative of a function.
Distinguish	Make clear the differences between two or more concepts or items.
Draw	Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.
Estimate	Obtain an approximate value.
Explain	Give a detailed account, including reasons or causes.
Find	Obtain an answer, showing relevant stages in the working.
Hence	Use the preceding work to obtain the required result.
Hence or otherwise	It is suggested that the preceding work is used, but other methods could also receive credit.
Identify	Provide an answer from a number of possibilities.

Integrate	Obtain the integral of a function.
Interpret	Use knowledge and understanding to recognize trends and draw conclusions from given information.
Investigate	Observe, study, or make a detailed and systematic examination, in order to establish facts and reach new conclusions.
Justify	Give valid reasons or evidence to support an answer or conclusion.
Label	Add labels to a diagram.
List	Give a sequence of brief answers with no explanation.
Plot	Mark the position of points on a diagram.
Predict	Give an expected result.
Prove	Use a sequence of logical steps to obtain the required result in a formal way.
Show	Give the steps in a calculation or derivation.
Show that	Obtain the required result (possibly using information given) without the formality of proof. "Show that" questions do not generally require the use of a calculator.
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.
Solve	Obtain the answer(s) using algebraic and/or numerical and/or graphical methods.
State	Give a specific name, value or other brief answer without explanation or calculation.
Suggest	Propose a solution, hypothesis or other possible answer.
Verify	Provide evidence that validates the result.
Write down	Obtain the answer(s), usually by extracting information. Little or no calculation is required. Working does not need to be shown.

Notation list

Of the various notations in use, the IB has chosen to adopt a system of notation based on the recommendations of the International Organization for Standardization (ISO). This notation is used in the examination papers for this course without explanation. If forms of notation other than those listed in this guide are used on a particular examination paper, they are defined within the question in which they appear.

Because students are required to recognize, though not necessarily use, IB notation in examinations, it is recommended that teachers introduce students to this notation at the earliest opportunity. Students are **not** allowed access to information about this notation in the examinations.

Students must always use correct mathematical notation, not calculator notation.

$\mathbb{N}$	the set of positive integers and zero, $\{0, 1, 2, 3, ...\}$
$\mathbb{Z}$	the set of integers, $\{0, \pm 1, \pm 2, \pm 3, ...\}$
$\mathbb{Z}^+$	the set of positive integers, $\{1, 2, 3, ...\}$
$\mathbb{Q}$	the set of rational numbers
$^+$	the set of positive rational numbers, $\{x \mid x \in \quad , x > 0\}$
$\mathbb{R}$	the set of real numbers
$\mathbb{R}^+$	the set of positive real numbers, $\{x \mid x \in \quad , x > 0\}$
$\mathbb{C}$	the set of complex numbers, $\{a + \mathrm{i}b \mid a, b \in \quad \}$
i	$\sqrt{-1}$
z	a complex number
z^*	the complex conjugate of z
$\lvert z \rvert$	the modulus of z
$\arg z$	the argument of z
$\mathrm{Re}\, z$	the real part of z
$\mathrm{Im}\, z$	the imaginary part of z
$\mathrm{cis}\,\theta$	$\cos\theta + \mathrm{i}\sin\theta$
$\{x_1, x_2, ...\}$	the set with elements $x_1, x_2, ...$
$n(A)$	the number of elements in the finite set A
$\{x \mid \quad \}$	the set of all x such that
$\in$	is an element of
$\notin$	is not an element of
$\varnothing$	the empty (null) set
U	the universal set
$\cup$	union
$\cap$	intersection

$\subset$	is a proper subset of
$\subseteq$	is a subset of
A'	the complement of the set A
$A \times B$	the Cartesian product of sets A and B (that is, $A \times B = \{(a, b) \mid a \in A,\ b \in B\}$)
$a \mid b$	a divides b
$a^{1/n}$, $\sqrt[n]{a}$	a to the power of $\frac{1}{n}$, n^{th} root of a (if $a \geq 0$ then $\sqrt[n]{a} \geq 0$)
$\lvert x \rvert$	the modulus or absolute value of x, that is $\begin{cases} x \text{ for } x \geq 0,\ x \in \\ -x \text{ for } x < 0,\ x \in \end{cases}$
$\equiv$	identity
$\approx$	is approximately equal to
$>$	is greater than
$\geq$	is greater than or equal to
$<$	is less than
$\leq$	is less than or equal to
$\ngtr$	is not greater than
$\nless$	is not less than
$\Rightarrow$	implies
$\Leftarrow$	is implied by
$\Leftrightarrow$	implies and is implied by
$[a, b]$	the closed interval $a \leq x \leq b$
$]a, b[$	the open interval $a < x < b$
u_n	the n^{th} term of a sequence or series
d	the common difference of an arithmetic sequence
r	the common ratio of a geometric sequence
S_n	the sum of the first n terms of a sequence, $u_1 + u_2 + ... + u_n$
S_∞	the sum to infinity of a sequence, $u_1 + u_2 + ...$
$\sum_{i=1}^{n} u_i$	$u_1 + u_2 + ... + u_n$
$\prod_{i=1}^{n} u_i$	$u_1 \times u_2 \times ... \times u_n$

$\binom{n}{r}$	$\dfrac{n!}{r!(n-r)!}$
$n!$	$n(n-1)(n-2)\times \ldots \times 3\times 2\times 1$
$f : A \to B$	f is a function under which each element of set A has an image in set B
$f : x \mapsto y$	f is a function under which x is mapped to y
$f(x)$	the image of x under the function f
f^{-1}	the inverse function of the function f
$f \circ g$	the composite function of f and g
$\lim\limits_{x\to a} f(x)$	the limit of $f(x)$ as x tends to a
$\dfrac{\mathrm{d}y}{\mathrm{d}x}$	the derivative of y with respect to x
$f'(x)$	the derivative of $f(x)$ with respect to x
$\dfrac{\mathrm{d}^2 y}{\mathrm{d}x^2}$	the second derivative of y with respect to x
$f''(x)$	the second derivative of $f(x)$ with respect to x
$\dfrac{\mathrm{d}^n y}{\mathrm{d}x^n}$	the n^{th} derivative of y with respect to x
$f^{(n)}(x)$	the n^{th} derivative of $f(x)$ with respect to x
$\int y\,\mathrm{d}x$	the indefinite integral of y with respect to x
$\int_a^b y\,\mathrm{d}x$	the definite integral of y with respect to x between the limits $x = a$ and $x = b$
e^x	the exponential function of x
$\log_a x$	the logarithm to the base a of x
$\ln x$	the natural logarithm of x, $\log_{\mathrm{e}} x$
sin, cos, tan	the circular functions
arcsin, arccos, arctan	the inverse circular functions
csc, sec, cot	the reciprocal circular functions
$\mathrm{A}(x, y)$	the point A in the plane with Cartesian coordinates x and y
[AB]	the line segment with end points A and B

AB	the length of [AB]
(AB)	the line containing points A and B
$\hat{A}$	the angle at A
$\text{C}\hat{\text{A}}\text{B}$	the angle between [CA] and [AB]
ΔABC	the triangle whose vertices are A, B and C
$\boldsymbol{v}$	the vector $\boldsymbol{v}$
$\overrightarrow{\text{AB}}$	the vector represented in magnitude and direction by the directed line segment from A to B
$\boldsymbol{a}$	the position vector $\overrightarrow{\text{OA}}$
$\boldsymbol{i}, \boldsymbol{j}, \boldsymbol{k}$	unit vectors in the directions of the Cartesian coordinate axes
$\lvert\boldsymbol{a}\rvert$	the magnitude of $\boldsymbol{a}$
$\lvert\overrightarrow{\text{AB}}\rvert$	the magnitude of $\overrightarrow{\text{AB}}$
$\boldsymbol{v} \cdot \boldsymbol{w}$	the scalar product of $\boldsymbol{v}$ and $\boldsymbol{w}$
$\boldsymbol{v} \times \boldsymbol{w}$	the vector product of $\boldsymbol{v}$ and $\boldsymbol{w}$
$\mathbf{I}$	the identity matrix
$\text{P}(A)$	the probability of event A
$\text{P}(A')$	the probability of the event "not A"
$\text{P}(A \mid B)$	the probability of the event A given B
$x_1, x_2, \ldots$	observations
$f_1, f_2, \ldots$	frequencies with which the observations $x_1, x_2, \ldots$ occur
P_x	the probability distribution function $\text{P}(X = x)$ of the discrete random variable X
$f(x)$	the probability density function of the continuous random variable X
$F(x)$	the cumulative distribution function of the continuous random variable X
$\text{E}(X)$	the expected value of the random variable X
$\text{Var}(X)$	the variance of the random variable X
μ	population mean
σ^2	population variance, $\sigma^2 = \dfrac{\sum_{i=1}^{k} f_i (x_i - \mu)^2}{n}$, where $n = \sum_{i=1}^{k} f_i$
σ	population standard deviation

$\bar{x}$	sample mean
s_n^2	sample variance, $s_n^2 = \dfrac{\sum_{i=1}^{k} f_i (x_i - \bar{x})^2}{n}$, where $n = \sum_{i=1}^{k} f_i$
s_n	standard deviation of the sample
s_{n-1}^2	unbiased estimate of the population variance, $s_{n-1}^2 = \dfrac{n}{n-1} s_n^2 = \dfrac{\sum_{i=1}^{k} f_i (x_i - \bar{x})^2}{n-1}$, where $n = \sum_{i=1}^{k} f_i$
$\mathrm{B}(n,\ p)$	binomial distribution with parameters n and p
$\mathrm{Po}(m)$	Poisson distribution with mean m
$\mathrm{N}(\mu, \sigma^2)$	normal distribution with mean μ and variance σ^2
$X \sim \mathrm{B}(n, p)$	the random variable X has a binomial distribution with parameters n and p
$X \sim \mathrm{Po}(m)$	the random variable X has a Poisson distribution with mean m
$X \sim \mathrm{N}(\mu, \sigma^2)$	the random variable X has a normal distribution with mean μ and variance σ^2
Φ	cumulative distribution function of the standardized normal variable with distribution $\mathrm{N}(0,1)$
ν	number of degrees of freedom
$A \setminus B$	the difference of the sets A and B (that is, $A \setminus B = A \cap B' = \{x \mid x \in A \text{ and } x \notin B\}$)
$A \Delta B$	the symmetric difference of the sets A and B (that is, $A \Delta B = (A \setminus B) \cup (B \setminus A)$)
κ_n	a complete graph with n vertices
$\kappa_{n,m}$	a complete bipartite graph with one set of n vertices and another set of m vertices
$_p$	the set of equivalence classes $\{0, 1, 2, \quad , p-1\}$ of integers modulo p
$\gcd(a,b)$	the greatest common divisor of integers a and b
$\mathrm{lcm}(a,b)$	the least common multiple of integers a and b
$\boldsymbol{A}_G$	the adjacency matrix of graph G
$\boldsymbol{C}_G$	the cost adjacency matrix of graph G

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Diploma Programme

Mathematics SL guide

First examinations 2014

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IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

IB learners strive to be:

Inquirers	They develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning will be sustained throughout their lives.
Knowledgeable	They explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines.
Thinkers	They exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions.
Communicators	They understand and express ideas and information confidently and creatively in more than one language and in a variety of modes of communication. They work effectively and willingly in collaboration with others.
Principled	They act with integrity and honesty, with a strong sense of fairness, justice and respect for the dignity of the individual, groups and communities. They take responsibility for their own actions and the consequences that accompany them.
Open-minded	They understand and appreciate their own cultures and personal histories, and are open to the perspectives, values and traditions of other individuals and communities. They are accustomed to seeking and evaluating a range of points of view, and are willing to grow from the experience.
Caring	They show empathy, compassion and respect towards the needs and feelings of others. They have a personal commitment to service, and act to make a positive difference to the lives of others and to the environment.
Risk-takers	They approach unfamiliar situations and uncertainty with courage and forethought, and have the independence of spirit to explore new roles, ideas and strategies. They are brave and articulate in defending their beliefs.
Balanced	They understand the importance of intellectual, physical and emotional balance to achieve personal well-being for themselves and others.
Reflective	They give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development.

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Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This guide can be found on the subject page of the online curriculum centre (OCC) at http://occ.ibo.org, a password-protected IB website designed to support IB teachers. It can also be purchased from the IB store at http://store.ibo.org.

Additional resources

Additional publications such as teacher support materials, subject reports, internal assessment guidance and grade descriptors can also be found on the OCC. Specimen and past examination papers as well as markschemes can be purchased from the IB store.

Teachers are encouraged to check the OCC for additional resources created or used by other teachers. Teachers can provide details of useful resources, for example: websites, books, videos, journals or teaching ideas.

First examinations 2014

The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme hexagon

The course is presented as six academic areas enclosing a central core (see figure 1). It encourages the concurrent study of a broad range of academic areas. Students study: two modern languages (or a modern language and a classical language); a humanities or social science subject; an experimental science; mathematics; one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.

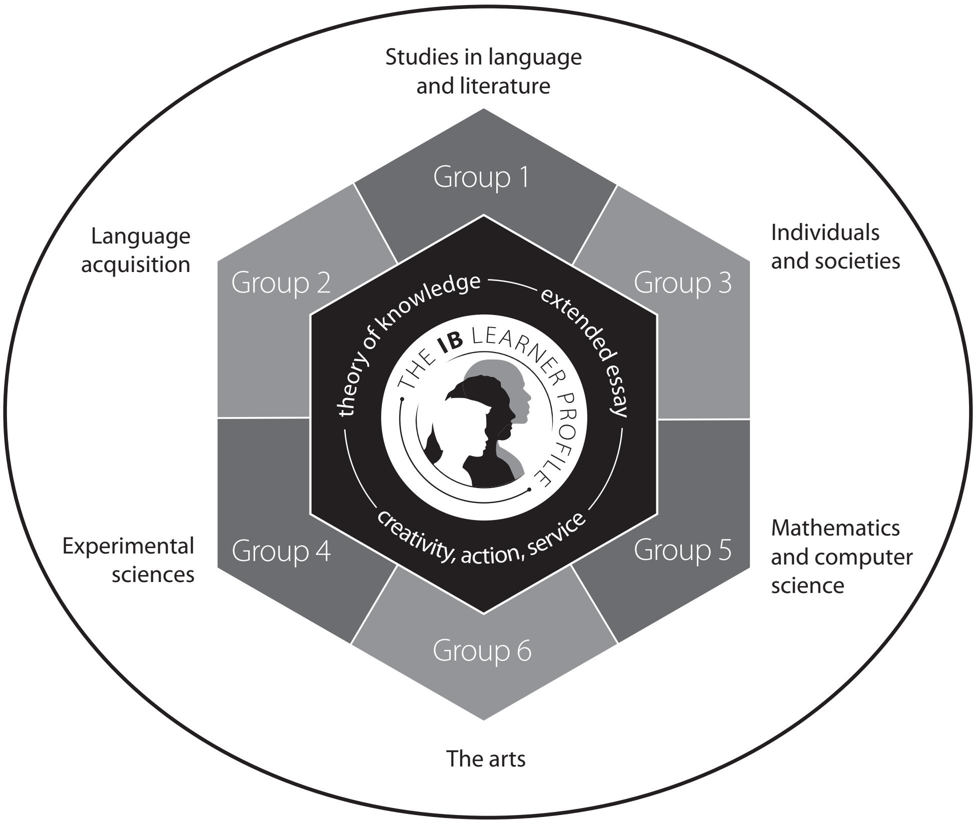

Figure 1
Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can choose a second subject from groups 1 to 5 instead of a group 6 subject. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers. The courses are available for examinations in English, French and Spanish, with the exception of groups 1 and 2 courses where examinations are in the language of study.

The core of the hexagon

All Diploma Programme students participate in the three course requirements that make up the core of the hexagon. Reflection on all these activities is a principle that lies at the heart of the thinking behind the Diploma Programme.

The theory of knowledge course encourages students to think about the nature of knowledge, to reflect on the process of learning in all the subjects they study as part of their Diploma Programme course, and to make connections across the academic areas. The extended essay, a substantial piece of writing of up to 4,000 words, enables students to investigate a topic of special interest that they have chosen themselves. It also encourages them to develop the skills of independent research that will be expected at university. Creativity, action, service involves students in experiential learning through a range of artistic, sporting, physical and service activities.

The IB mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IB, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

Nature of the subject

Introduction

The nature of mathematics can be summarized in a number of ways: for example, it can be seen as a well-defined body of knowledge, as an abstract system of ideas, or as a useful tool. For many people it is probably a combination of these, but there is no doubt that mathematical knowledge provides an important key to understanding the world in which we live. Mathematics can enter our lives in a number of ways: we buy produce in the market, consult a timetable, read a newspaper, time a process or estimate a length. Mathematics, for most of us, also extends into our chosen profession: visual artists need to learn about perspective; musicians need to appreciate the mathematical relationships within and between different rhythms; economists need to recognize trends in financial dealings; and engineers need to take account of stress patterns in physical materials. Scientists view mathematics as a language that is central to our understanding of events that occur in the natural world. Some people enjoy the challenges offered by the logical methods of mathematics and the adventure in reason that mathematical proof has to offer. Others appreciate mathematics as an aesthetic experience or even as a cornerstone of philosophy. This prevalence of mathematics in our lives, with all its interdisciplinary connections, provides a clear and sufficient rationale for making the study of this subject compulsory for students studying the full diploma.

Summary of courses available

Because individual students have different needs, interests and abilities, there are four different courses in mathematics. These courses are designed for different types of students: those who wish to study mathematics in depth, either as a subject in its own right or to pursue their interests in areas related to mathematics; those who wish to gain a degree of understanding and competence to understand better their approach to other subjects; and those who may not as yet be aware how mathematics may be relevant to their studies and in their daily lives. Each course is designed to meet the needs of a particular group of students. Therefore, great care should be taken to select the course that is most appropriate for an individual student.

In making this selection, individual students should be advised to take account of the following factors:

- their own abilities in mathematics and the type of mathematics in which they can be successful
- their own interest in mathematics and those particular areas of the subject that may hold the most interest for them
- their other choices of subjects within the framework of the Diploma Programme
- their academic plans, in particular the subjects they wish to study in future
- their choice of career.

Teachers are expected to assist with the selection process and to offer advice to students.

Mathematical studies SL

This course is available only at standard level, and is equivalent in status to mathematics SL, but addresses different needs. It has an emphasis on applications of mathematics, and the largest section is on statistical techniques. It is designed for students with varied mathematical backgrounds and abilities. It offers students opportunities to learn important concepts and techniques and to gain an understanding of a wide variety of mathematical topics. It prepares students to be able to solve problems in a variety of settings, to develop more sophisticated mathematical reasoning and to enhance their critical thinking. The individual project is an extended piece of work based on personal research involving the collection, analysis and evaluation of data. Students taking this course are well prepared for a career in social sciences, humanities, languages or arts. These students may need to utilize the statistics and logical reasoning that they have learned as part of the mathematical studies SL course in their future studies.

Mathematics SL

This course caters for students who already possess knowledge of basic mathematical concepts, and who are equipped with the skills needed to apply simple mathematical techniques correctly. The majority of these students will expect to need a sound mathematical background as they prepare for future studies in subjects such as chemistry, economics, psychology and business administration.

Mathematics HL

This course caters for students with a good background in mathematics who are competent in a range of analytical and technical skills. The majority of these students will be expecting to include mathematics as a major component of their university studies, either as a subject in its own right or within courses such as physics, engineering and technology. Others may take this subject because they have a strong interest in mathematics and enjoy meeting its challenges and engaging with its problems.

Further mathematics HL

This course is available only at higher level. It caters for students with a very strong background in mathematics who have attained a high degree of competence in a range of analytical and technical skills, and who display considerable interest in the subject. Most of these students will expect to study mathematics at university, either as a subject in its own right or as a major component of a related subject. The course is designed specifically to allow students to learn about a variety of branches of mathematics in depth and also to appreciate practical applications. It is expected that students taking this course will also be taking mathematics HL.

Note: Mathematics HL is an ideal course for students expecting to include mathematics as a major component of their university studies, either as a subject in its own right or within courses such as physics, engineering or technology. It should not be regarded as necessary for such students to study further mathematics HL. Rather, further mathematics HL is an optional course for students with a particular aptitude and interest in mathematics, enabling them to study some wider and deeper aspects of mathematics, but is by no means a necessary qualification to study for a degree in mathematics.

Mathematics SL—course details

The course focuses on introducing important mathematical concepts through the development of mathematical techniques. The intention is to introduce students to these concepts in a comprehensible and coherent way, rather than insisting on the mathematical rigour required for mathematics HL. Students should, wherever possible, apply the mathematical knowledge they have acquired to solve realistic problems set in an appropriate context.

The internally assessed component, the exploration, offers students the opportunity for developing independence in their mathematical learning. Students are encouraged to take a considered approach to various mathematical activities and to explore different mathematical ideas. The exploration also allows students to work without the time constraints of a written examination and to develop the skills they need for communicating mathematical ideas.

This course does not have the depth found in the mathematics HL courses. Students wishing to study subjects with a high degree of mathematical content should therefore opt for a mathematics HL course rather than a mathematics SL course.

Prior learning

Mathematics is a linear subject, and it is expected that most students embarking on a Diploma Programme (DP) mathematics course will have studied mathematics for at least 10 years. There will be a great variety of topics studied, and differing approaches to teaching and learning. Thus students will have a wide variety of skills and knowledge when they start the mathematics SL course. Most will have some background in arithmetic, algebra, geometry, trigonometry, probability and statistics. Some will be familiar with an inquiry approach, and may have had an opportunity to complete an extended piece of work in mathematics.

At the beginning of the syllabus section there is a list of topics that are considered to be prior learning for the mathematics SL course. It is recognized that this may contain topics that are unfamiliar to some students, but it is anticipated that there may be other topics in the syllabus itself that these students have already encountered. Teachers should plan their teaching to incorporate topics mentioned that are unfamiliar to their students.

Links to the Middle Years Programme

The prior learning topics for the DP courses have been written in conjunction with the Middle Years Programme (MYP) mathematics guide. The approaches to teaching and learning for DP mathematics build on the approaches used in the MYP. These include investigations, exploration and a variety of different assessment tools.

A continuum document called *Mathematics: The MYP–DP continuum* (November 2010) is available on the DP mathematics home pages of the OCC. This extensive publication focuses on the alignment of mathematics across the MYP and the DP. It was developed in response to feedback provided by IB World Schools, which expressed the need to articulate the transition of mathematics from the MYP to the DP. The publication also highlights the similarities and differences between MYP and DP mathematics, and is a valuable resource for teachers.

Mathematics and theory of knowledge

The *Theory of knowledge guide* (March 2006) identifies four ways of knowing, and it could be claimed that these all have some role in the acquisition of mathematical knowledge. While perhaps initially inspired by data from sense perception, mathematics is dominated by reason, and some mathematicians argue that their subject is a language, that it is, in some sense, universal. However, there is also no doubt that mathematicians perceive beauty in mathematics, and that emotion can be a strong driver in the search for mathematical knowledge.

As an area of knowledge, mathematics seems to supply a certainty perhaps missing in other disciplines. This may be related to the “purity” of the subject that makes it sometimes seem divorced from reality. However, mathematics has also provided important knowledge about the world, and the use of mathematics in science and technology has been one of the driving forces for scientific advances.

Despite all its undoubted power for understanding and change, mathematics is in the end a puzzling phenomenon. A fundamental question for all knowers is whether mathematical knowledge really exists independently of our thinking about it. Is it there “waiting to be discovered” or is it a human creation?

Students' attention should be drawn to questions relating theory of knowledge (TOK) and mathematics, and they should be encouraged to raise such questions themselves, in mathematics and TOK classes. This includes questioning all the claims made above. Examples of issues relating to TOK are given in the "Links" column of the syllabus. Teachers could also discuss questions such as those raised in the "Areas of knowledge" section of the TOK guide.

Mathematics and the international dimension

Mathematics is in a sense an international language, and, apart from slightly differing notation, mathematicians from around the world can communicate within their field. Mathematics transcends politics, religion and nationality, yet throughout history great civilizations owe their success in part to their mathematicians being able to create and maintain complex social and architectural structures.

Despite recent advances in the development of information and communication technologies, the global exchange of mathematical information and ideas is not a new phenomenon and has been essential to the progress of mathematics. Indeed, many of the foundations of modern mathematics were laid many centuries ago by Arabic, Greek, Indian and Chinese civilizations, among others. Teachers could use timeline websites to show the contributions of different civilizations to mathematics, but not just for their mathematical content. Illustrating the characters and personalities of the mathematicians concerned and the historical context in which they worked brings home the human and cultural dimension of mathematics.

The importance of science and technology in the everyday world is clear, but the vital role of mathematics is not so well recognized. It is the language of science, and underpins most developments in science and technology. A good example of this is the digital revolution, which is transforming the world, as it is all based on the binary number system in mathematics.

Many international bodies now exist to promote mathematics. Students are encouraged to access the extensive websites of international mathematical organizations to enhance their appreciation of the international dimension and to engage in the global issues surrounding the subject.

Examples of global issues relating to international-mindedness (**Int**) are given in the "Links" column of the syllabus.

Aims

Group 5 aims

The aims of all mathematics courses in group 5 are to enable students to:

1. enjoy mathematics, and develop an appreciation of the elegance and power of mathematics
2. develop an understanding of the principles and nature of mathematics
3. communicate clearly and confidently in a variety of contexts
4. develop logical, critical and creative thinking, and patience and persistence in problem-solving
5. employ and refine their powers of abstraction and generalization
6. apply and transfer skills to alternative situations, to other areas of knowledge and to future developments
7. appreciate how developments in technology and mathematics have influenced each other
8. appreciate the moral, social and ethical implications arising from the work of mathematicians and the applications of mathematics
9. appreciate the international dimension in mathematics through an awareness of the universality of mathematics and its multicultural and historical perspectives
10. appreciate the contribution of mathematics to other disciplines, and as a particular "area of knowledge" in the TOK course.

Assessment objectives

Problem-solving is central to learning mathematics and involves the acquisition of mathematical skills and concepts in a wide range of situations, including non-routine, open-ended and real-world problems. Having followed a DP mathematics SL course, students will be expected to demonstrate the following.

1. **Knowledge and understanding**: recall, select and use their knowledge of mathematical facts, concepts and techniques in a variety of familiar and unfamiliar contexts.
2. **Problem-solving**: recall, select and use their knowledge of mathematical skills, results and models in both real and abstract contexts to solve problems.
3. **Communication and interpretation**: transform common realistic contexts into mathematics; comment on the context; sketch or draw mathematical diagrams, graphs or constructions both on paper and using technology; record methods, solutions and conclusions using standardized notation.
4. **Technology**: use technology, accurately, appropriately and efficiently both to explore new ideas and to solve problems.
5. **Reasoning**: construct mathematical arguments through use of precise statements, logical deduction and inference, and by the manipulation of mathematical expressions.
6. **Inquiry approaches**: investigate unfamiliar situations, both abstract and real-world, involving organizing and analysing information, making conjectures, drawing conclusions and testing their validity.

Syllabus outline

Syllabus component	Teaching hours
	SL
All topics are compulsory. Students must study all the sub-topics in each of the topics in the syllabus as listed in this guide. Students are also required to be familiar with the topics listed as prior learning.	
Topic 1 Algebra	9
Topic 2 Functions and equations	24
Topic 3 Circular functions and trigonometry	16
Topic 4 Vectors	16
Topic 5 Statistics and probability	35
Topic 6 Calculus	40
Mathematical exploration Internal assessment in mathematics SL is an individual exploration. This is a piece of written work that involves investigating an area of mathematics.	10
Total teaching hours	**150**

Approaches to the teaching and learning of mathematics SL

Throughout the DP mathematics SL course, students should be encouraged to develop their understanding of the methodology and practice of the discipline of mathematics. The processes of **mathematical inquiry**, **mathematical modelling and applications** and the **use of technology** should be introduced appropriately. These processes should be used throughout the course, and not treated in isolation.

Mathematical inquiry

The IB learner profile encourages learning by experimentation, questioning and discovery. In the IB classroom, students should generally learn mathematics by being active participants in learning activities rather than recipients of instruction. Teachers should therefore provide students with opportunities to learn through mathematical inquiry. This approach is illustrated in figure 2.

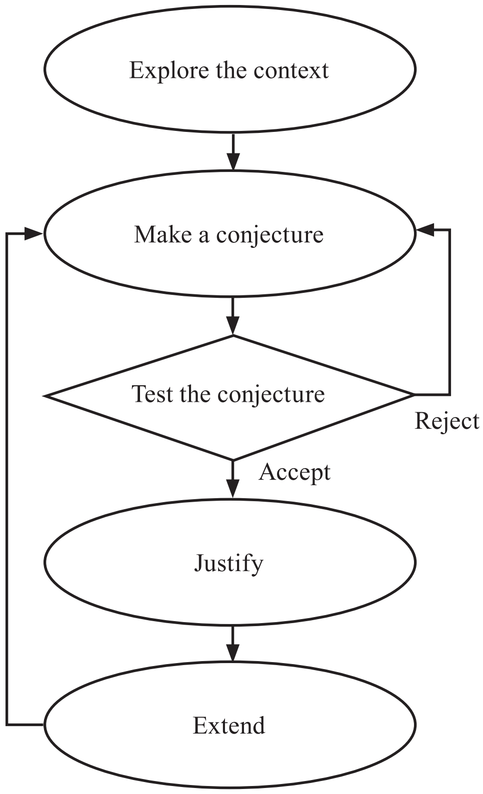

Figure 2

Mathematical modelling and applications

Students should be able to use mathematics to solve problems in the real world. Engaging students in the mathematical modelling process provides such opportunities. Students should develop, apply and critically analyse models. This approach is illustrated in figure 3.

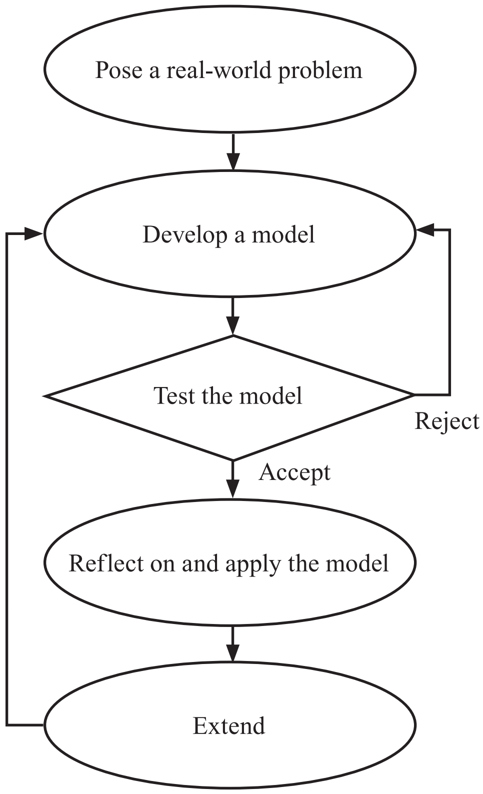

Figure 3

Technology

Technology is a powerful tool in the teaching and learning of mathematics. Technology can be used to enhance visualization and support student understanding of mathematical concepts. It can assist in the collection, recording, organization and analysis of data. Technology can increase the scope of the problem situations that are accessible to students. The use of technology increases the feasibility of students working with interesting problem contexts where students reflect, reason, solve problems and make decisions.

As teachers tie together the unifying themes of **mathematical inquiry**, **mathematical modelling and applications** and the **use of technology**, they should begin by providing substantial guidance, and then gradually encourage students to become more independent as inquirers and thinkers. IB students should learn to become strong communicators through the language of mathematics. Teachers should create a safe learning environment in which students are comfortable as risk-takers.

Teachers are encouraged to relate the mathematics being studied to other subjects and to the real world, especially topics that have particular relevance or are of interest to their students. Everyday problems and questions should be drawn into the lessons to motivate students and keep the material relevant; suggestions are provided in the "Links" column of the syllabus. The mathematical exploration offers an opportunity to investigate the usefulness, relevance and occurrence of mathematics in the real world and will add an extra dimension to the course. The emphasis is on communication by means of mathematical forms (for example, formulae, diagrams, graphs and so on) with accompanying commentary. Modelling, investigation, reflection, personal engagement and mathematical communication should therefore feature prominently in the DP mathematics classroom.

For further information on “Approaches to teaching a DP course”, please refer to the publication *The Diploma Programme: From principles into practice* (April 2009). To support teachers, a variety of resources can be found on the OCC and details of workshops for professional development are available on the public website.

Format of the syllabus

- **Content:** this column lists, under each topic, the sub-topics to be covered.
- **Further guidance:** this column contains more detailed information on specific sub-topics listed in the content column. This clarifies the content for examinations.
- **Links:** this column provides useful links to the aims of the mathematics SL course, with suggestions for discussion, real-life examples and ideas for further investigation. **These suggestions are only a guide for introducing and illustrating the sub-topic and are not exhaustive.** Links are labelled as follows.

  Appl real-life examples and links to other DP subjects

  Aim 8 moral, social and ethical implications of the sub-topic

  Int international-mindedness

  TOK suggestions for discussion

Note that any syllabus references to other subject guides given in the “Links” column are correct for the current (2012) published versions of the guides.

Notes on the syllabus

- Formulae are only included in this document where there may be some ambiguity. All formulae required for the course are in the mathematics SL formula booklet.
- The term “technology” is used for any form of calculator or computer that may be available. However, there will be restrictions on which technology may be used in examinations, which will be noted in relevant documents.
- The terms “analysis” and “analytic approach” are generally used when referring to an approach that does not use technology.

Course of study

The content of all six topics in the syllabus must be taught, although not necessarily in the order in which they appear in this guide. Teachers are expected to construct a course of study that addresses the needs of their students and includes, where necessary, the topics noted in prior learning.

Integration of the mathematical exploration

Work leading to the completion of the exploration should be integrated into the course of study. Details of how to do this are given in the section on internal assessment and in the teacher support material.

Time allocation

The recommended teaching time for standard level courses is 150 hours. For mathematics SL, it is expected that 10 hours will be spent on work for the exploration. The time allocations given in this guide are approximate, and are intended to suggest how the remaining 140 hours allowed for the teaching of the syllabus might be allocated. However, the exact time spent on each topic depends on a number of factors, including the background knowledge and level of preparedness of each student. Teachers should therefore adjust these timings to correspond to the needs of their students.

Use of calculators

Students are expected to have access to a graphic display calculator (GDC) at all times during the course. The minimum requirements are reviewed as technology advances, and updated information will be provided to schools. It is expected that teachers and schools monitor calculator use with reference to the calculator policy. Regulations covering the types of calculators allowed in examinations are provided in the *Handbook of procedures for the Diploma Programme*. Further information and advice is provided in the *Mathematics HL/SL: Graphic display calculators teacher support material* (May 2005) and on the OCC.

Mathematics SL formula booklet

Each student is required to have access to a clean copy of this booklet during the examination. It is recommended that teachers ensure students are familiar with the contents of this document from the beginning of the course. It is the responsibility of the school to download a copy from IBIS or the OCC, check that there are no printing errors, and ensure that there are sufficient copies available for all students.

Teacher support materials

A variety of teacher support materials will accompany this guide. These materials will include guidance for teachers on the introduction, planning and marking of the exploration, and specimen examination papers and markschemes.

Command terms and notation list

Teachers and students need to be familiar with the IB notation and the command terms, as these will be used without explanation in the examination papers. The “Glossary of command terms” and “Notation list” appear as appendices in this guide.

Prior learning topics

As noted in the previous section on prior learning, it is expected that all students have extensive previous mathematical experiences, but these will vary. It is expected that mathematics SL students will be familiar with the following topics before they take the examinations, because questions assume knowledge of them. Teachers must therefore ensure that any topics listed here that are unknown to their students at the start of the course are included at an early stage. They should also take into account the existing mathematical knowledge of their students to design an appropriate course of study for mathematics SL. This table lists the knowledge, together with the syllabus content, that is essential to successful completion of the mathematics SL course.

Students must be familiar with SI (*Système International*) units of length, mass and time, and their derived units.

Topic	Content
Number	Routine use of addition, subtraction, multiplication and division, using integers, decimals and fractions, including order of operations. Simple positive exponents. Simplification of expressions involving roots (surds or radicals). Prime numbers and factors, including greatest common divisors and least common multiples. Simple applications of ratio, percentage and proportion, linked to similarity. Definition and elementary treatment of absolute value (modulus), $\lvert a \rvert$. Rounding, decimal approximations and significant figures, including appreciation of errors. Expression of numbers in standard form (scientific notation), that is, $a \times 10^k$, $1 \le a < 10$, $k \in \mathbb{Z}$.
Sets and numbers	Concept and notation of sets, elements, universal (reference) set, empty (null) set, complement, subset, equality of sets, disjoint sets. Operations on sets: union and intersection. Commutative, associative and distributive properties. Venn diagrams. Number systems: natural numbers; integers, $\mathbb{Z}$; rationals, $\mathbb{Q}$, and irrationals; real numbers, $\mathbb{R}$. Intervals on the real number line using set notation and using inequalities. Expressing the solution set of a linear inequality on the number line and in set notation. Mappings of the elements of one set to another. Illustration by means of sets of ordered pairs, tables, diagrams and graphs.
Algebra	Manipulation of simple algebraic expressions involving factorization and expansion, including quadratic expressions. Rearrangement, evaluation and combination of simple formulae. Examples from other subject areas, particularly the sciences, should be included. The linear function and its graph, gradient and y-intercept. Addition and subtraction of algebraic fractions. The properties of order relations: $<, \le, >, \ge$. Solution of equations and inequalities in one variable, including cases with rational coefficients. Solution of simultaneous equations in two variables.

Topic	Content
Trigonometry	Angle measurement in degrees. Compass directions and three figure bearings. Right-angle trigonometry. Simple applications for solving triangles. Pythagoras' theorem and its converse.
Geometry	Simple geometric transformations: translation, reflection, rotation, enlargement. Congruence and similarity, including the concept of scale factor of an enlargement. The circle, its centre and radius, area and circumference. The terms "arc", "sector", "chord", "tangent" and "segment". Perimeter and area of plane figures. Properties of triangles and quadrilaterals, including parallelograms, rhombuses, rectangles, squares, kites and trapeziums (trapezoids); compound shapes. Volumes of prisms, pyramids, spheres, cylinders and cones.
Coordinate geometry	Elementary geometry of the plane, including the concepts of dimension for point, line, plane and space. The equation of a line in the form $y = mx + c$. Parallel and perpendicular lines, including $m_1 = m_2$ and $m_1 m_2 = -1$. Geometry of simple plane figures. The Cartesian plane: ordered pairs (x, y), origin, axes. Mid-point of a line segment and distance between two points in the Cartesian plane and in three dimensions.
Statistics and probability	Descriptive statistics: collection of raw data; display of data in pictorial and diagrammatic forms, including pie charts, pictograms, stem and leaf diagrams, bar graphs and line graphs. Obtaining simple statistics from discrete and continuous data, including mean, median, mode, quartiles, range, interquartile range. Calculating probabilities of simple events.

Syllabus content

Topic 1—Algebra 9 hours

The aim of this topic is to introduce students to some basic algebraic concepts and applications.

	Content	Further guidance	Links
1.1	Arithmetic sequences and series; sum of finite arithmetic series; geometric sequences and series; sum of finite and infinite geometric series. Sigma notation. Applications.	Technology may be used to generate and display sequences in several ways. Link to 2.6, exponential functions. Examples include compound interest and population growth.	**Int:** The chess legend (Sissa ibn Dahir). **Int:** Aryabhatta is sometimes considered the “father of algebra”. Compare with al-Khawarizmi. **TOK:** How did Gauss add up integers from 1 to 100? Discuss the idea of mathematical intuition as the basis for formal proof. **TOK:** Debate over the validity of the notion of “infinity”: finitists such as L. Kronecker consider that “a mathematical object does not exist unless it can be constructed from natural numbers in a finite number of steps”. **TOK:** What is Zeno’s dichotomy paradox? How far can mathematical facts be from intuition?

	Content	Further guidance	Links
1.2	Elementary treatment of exponents and logarithms. Laws of exponents; laws of logarithms. Change of base.	*Examples*: $16^{\frac{3}{4}} = 8$; $\frac{3}{4} = \log_{16} 8$; $\log 32 = 5\log 2$; $(2^3)^{-4} = 2^{-12}$. *Examples*: $\log_4 7 = \frac{\ln 7}{\ln 4}$, $\log_{25} 125 = \frac{\log_5 125}{\log_5 25} \left(= \frac{3}{2}\right)$. Link to 2.6, logarithmic functions.	**Appl:** Chemistry 18.1 (Calculation of pH). **TOK:** Are logarithms an invention or discovery? (This topic is an opportunity for teachers to generate reflection on “the nature of mathematics”.)
1.3	The binomial theorem: expansion of $(a+b)^n$, $n \in \mathbb{N}$. Calculation of binomial coefficients using Pascal’s triangle and $\binom{n}{r}$. **Not required:** formal treatment of permutations and formula for ${}^nP_r$.	Counting principles may be used in the development of the theorem. $\binom{n}{r}$ should be found using **both** the formula and technology. *Example*: finding $\binom{6}{r}$ from inputting $y = 6^nC_rX$ and then reading coefficients from the table. Link to 5.8, binomial distribution.	**Aim 8:** Pascal’s triangle. Attributing the origin of a mathematical discovery to the wrong mathematician. **Int:** The so-called “Pascal’s triangle” was known in China much earlier than Pascal.

Topic 2—Functions and equations 24 hours

The aims of this topic are to explore the notion of a function as a unifying theme in mathematics, and to apply functional methods to a variety of mathematical situations. It is expected that extensive use will be made of technology in both the development and the application of this topic, rather than elaborate analytical techniques. On examination papers, questions may be set requiring the graphing of functions that do not explicitly appear on the syllabus, and students may need to choose the appropriate viewing window. For those functions explicitly mentioned, questions may also be set on composition of these functions with the linear function $y = ax + b$.

	Content	Further guidance	Links
2.1	Concept of function $f : x \mapsto f(x)$. Domain, range; image (value). Composite functions. Identity function. Inverse function f^{-1}. **Not required:** domain restriction.	*Example*: for $x \mapsto \sqrt{2-x}$, domain is $x \le 2$, range is $y \ge 0$. A graph is helpful in visualizing the range. $(f \circ g)(x) = f(g(x))$. $(f \circ f^{-1})(x) = (f^{-1} \circ f)(x) = x$. On examination papers, students will only be asked to find the inverse of a *one-to-one* function.	**Int:** The development of functions, Rene Descartes (France), Gottfried Wilhelm Leibniz (Germany) and Leonhard Euler (Switzerland). **TOK:** Is zero the same as "nothing"? **TOK:** Is mathematics a formal language?
2.2	The graph of a function; its equation $y = f(x)$. Function graphing skills. Investigation of key features of graphs, such as maximum and minimum values, intercepts, horizontal and vertical asymptotes, symmetry, and consideration of domain and range. Use of technology to graph a variety of functions, including ones not specifically mentioned. The graph of $y = f^{-1}(x)$ as the reflection in the line $y = x$ of the graph of $y = f(x)$.	**Note** the difference in the command terms "draw" and "sketch". An analytic approach is also expected for simple functions, including all those listed under topic 2. Link to 6.3, local maximum and minimum points.	**Appl:** Chemistry 11.3.1 (sketching and interpreting graphs); geographic skills. **TOK:** How accurate is a visual representation of a mathematical concept? (Limits of graphs in delivering information about functions and phenomena in general, relevance of modes of representation.)

	Content	Further guidance	Links
2.3	Transformations of graphs. Translations: $y = f(x) + b$; $y = f(x-a)$. Reflections (in both axes): $y = -f(x)$; $y = f(-x)$. Vertical stretch with scale factor p: $y = pf(x)$. Stretch in the x-direction with scale factor $\frac{1}{q}$: $y = f(qx)$. Composite transformations.	Technology should be used to investigate these transformations. Translation by the vector $\begin{pmatrix} 3 \\ -2 \end{pmatrix}$ denotes horizontal shift of 3 units to the right, and vertical shift of 2 down. *Example*: $y = x^2$ used to obtain $y = 3x^2 + 2$ by a stretch of scale factor 3 in the y-direction followed by a translation of $\begin{pmatrix} 0 \\ 2 \end{pmatrix}$.	**Appl:** Economics 1.1 (shifting of supply and demand curves).
2.4	The quadratic function $x \mapsto ax^2 + bx + c$: its graph, y-intercept $(0, c)$. Axis of symmetry. The form $x \mapsto a(x-p)(x-q)$, x-intercepts $(p, 0)$ and $(q, 0)$. The form $x \mapsto a(x-h)^2 + k$, vertex (h, k).	Candidates are expected to be able to change from one form to another. Links to 2.3, transformations; 2.7, quadratic equations.	**Appl:** Chemistry 17.2 (equilibrium law). **Appl:** Physics 2.1 (kinematics). **Appl:** Physics 4.2 (simple harmonic motion). **Appl:** Physics 9.1 (HL only) (projectile motion).

	Content	Further guidance	Links
2.5	The reciprocal function $x \mapsto \frac{1}{x}$, $x \neq 0$: its graph and self-inverse nature.		
	The rational function $x \mapsto \frac{ax+b}{cx+d}$ and its graph.	*Examples*: $h(x) = \frac{4}{3x-2}$, $x \neq \frac{2}{3}$; $y = \frac{x+7}{2x-5}$, $x \neq \frac{5}{2}$.	
	Vertical and horizontal asymptotes.	Diagrams should include all asymptotes and intercepts.	
2.6	Exponential functions and their graphs: $x \mapsto a^x$, $a > 0$, $x \mapsto e^x$.		**Int:** The Babylonian method of multiplication: $ab = \frac{(a+b)^2 - a^2 - b^2}{2}$. Sulba Sutras in ancient India and the Bakhshali Manuscript contained an algebraic formula for solving quadratic equations.
	Logarithmic functions and their graphs: $x \mapsto \log_a x$, $x > 0$, $x \mapsto \ln x$, $x > 0$.	Links to 1.1, geometric sequences; 1.2, laws of exponents and logarithms; 2.1, inverse functions; 2.2, graphs of inverses; and 6.1, limits.	
	Relationships between these functions: $a^x = e^{x \ln a}$; $\log_a a^x = x$; $a^{\log_a x} = x$, $x > 0$.		

	Content	Further guidance	Links
2.7	Solving equations, both graphically and analytically. Use of technology to solve a variety of equations, including those where there is no appropriate analytic approach.	Solutions may be referred to as roots of equations or zeros of functions. Links to 2.2, function graphing skills; and 2.3–2.6, equations involving specific functions. *Examples*: $e^x = \sin x$, $x^4 + 5x - 6 = 0$.	
	Solving $ax^2 + bx + c = 0$, $a \neq 0$. The quadratic formula.		
	The discriminant $\Delta = b^2 - 4ac$ and the nature of the roots, that is, two distinct real roots, two equal real roots, no real roots.	*Example*: Find k given that the equation $3kx^2 + 2x + k = 0$ has two equal real roots.	
	Solving exponential equations.	*Examples*: $2^{x-1} = 10$, $\left(\frac{1}{3}\right)^x = 9^{x+1}$. Link to 1.2, exponents and logarithms.	
2.8	Applications of graphing skills and solving equations that relate to real-life situations.	Link to 1.1, geometric series.	**Appl:** Compound interest, growth and decay; projectile motion; braking distance; electrical circuits. **Appl:** Physics 7.2.7–7.2.9, 13.2.5, 13.2.6, 13.2.8 (radioactive decay and half-life)

Topic 3—Circular functions and trigonometry 16 hours

The aims of this topic are to explore the circular functions and to solve problems using trigonometry. On examination papers, radian measure should be assumed unless otherwise indicated.

	Content	Further guidance	Links
3.1	The circle: radian measure of angles; length of an arc; area of a sector.	Radian measure may be expressed as exact multiples of π, or decimals.	**Int:** Seki Takakazu calculating π to ten decimal places. **Int:** Hipparchus, Menelaus and Ptolemy. **Int:** Why are there 360 degrees in a complete turn? Links to Babylonian mathematics. **TOK:** Which is a better measure of angle: radian or degree? What are the "best" criteria by which to decide? **TOK:** Euclid's axioms as the building blocks of Euclidean geometry. Link to non-Euclidean geometry.
3.2	Definition of $\cos\theta$ and $\sin\theta$ in terms of the unit circle. Definition of $\tan\theta$ as $\dfrac{\sin\theta}{\cos\theta}$. Exact values of trigonometric ratios of $0, \dfrac{\pi}{6}, \dfrac{\pi}{4}, \dfrac{\pi}{3}, \dfrac{\pi}{2}$ and their multiples.	The equation of a straight line through the origin is $y = x\tan\theta$. *Examples*: $\sin\dfrac{\pi}{3} = \dfrac{\sqrt{3}}{2}$, $\cos\dfrac{3\pi}{4} = -\dfrac{1}{\sqrt{2}}$, $\tan 210° = \dfrac{\sqrt{3}}{3}$.	**Aim 8:** Who really invented "Pythagoras' theorem"? **Int:** The first work to refer explicitly to the sine as a function of an angle is the Aryabhatiya of Aryabhata (ca. 510). **TOK:** Trigonometry was developed by successive civilizations and cultures. How is mathematical knowledge considered from a sociocultural perspective?

	Content	Further guidance	Links
3.3	The Pythagorean identity $\cos^2\theta + \sin^2\theta = 1$.	Simple geometrical diagrams and/or technology may be used to illustrate the double angle formulae (and other trigonometric identities).	
	Double angle identities for sine and cosine.		
	Relationship between trigonometric ratios.	*Examples*: Given $\sin\theta$, finding possible values of $\tan\theta$ without finding θ. Given $\cos x = \frac{3}{4}$, and x is acute, find $\sin 2x$ without finding x.	
3.4	The circular functions $\sin x$, $\cos x$ and $\tan x$: their domains and ranges; amplitude, their periodic nature; and their graphs.		**Appl:** Physics 4.2 (simple harmonic motion).
	Composite functions of the form $f(x) = a\sin(b(x+c)) + d$.	*Examples*: $f(x) = \tan\left(x - \frac{\pi}{4}\right)$, $f(x) = 2\cos(3(x-4)) + 1$.	
	Transformations.	*Example*: $y = \sin x$ used to obtain $y = 3\sin 2x$ by a stretch of scale factor 3 in the y-direction and a stretch of scale factor $\frac{1}{2}$ in the x-direction. Link to 2.3, transformation of graphs.	
	Applications.	Examples include height of tide, motion of a Ferris wheel.	

	Content	Further guidance	Links
3.5	Solving trigonometric equations in a finite interval, both graphically and analytically.	*Examples*: $2\sin x = 1$, $0 \le x \le 2\pi$, $2\sin 2x = 3\cos x$, $0^{\circ} \le x \le 180^{\circ}$, $2\tan(3(x-4)) = 1$, $-\pi \le x \le 3\pi$.	
	Equations leading to quadratic equations in $\sin x$, $\cos x$ or $\tan x$. **Not required:** the general solution of trigonometric equations.	*Examples*: $2\sin^2 x + 5\cos x + 1 = 0$ for $0 \le x < 4\pi$, $2\sin x = \cos 2x$, $-\pi \le x \le \pi$.	
3.6	Solution of triangles.	Pythagoras' theorem is a special case of the cosine rule.	**Aim 8:** Attributing the origin of a mathematical discovery to the wrong mathematician.
	The cosine rule. The sine rule, including the ambiguous case.	Link with 4.2, scalar product, noting that: $\boldsymbol{c} = \boldsymbol{a} - \boldsymbol{b} \Rightarrow \lvert\boldsymbol{c}\rvert^2 = \lvert\boldsymbol{a}\rvert^2 + \lvert\boldsymbol{b}\rvert^2 - 2\boldsymbol{a}\cdot\boldsymbol{b}$.	**Int:** Cosine rule: Al-Kashi and Pythagoras.
	Area of a triangle, $\frac{1}{2}ab\sin C$.		
	Applications.	Examples include navigation, problems in two and three dimensions, including angles of elevation and depression.	**TOK:** Non-Euclidean geometry: angle sum on a globe greater than 180°.

Topic 4—Vectors 16 hours

The aim of this topic is to provide an elementary introduction to vectors, including both algebraic and geometric approaches. The use of dynamic geometry software is extremely helpful to visualize situations in three dimensions.

	Content	Further guidance	Links
4.1	Vectors as displacements in the plane and in three dimensions.	Link to three-dimensional geometry, x, y and z-axes.	**Appl:** Physics 1.3.2 (vector sums and differences) Physics 2.2.2, 2.2.3 (vector resultants). **TOK:** How do we relate a theory to the author? Who developed vector analysis: JW Gibbs or O Heaviside?
	Components of a vector; column representation; $\boldsymbol{v}=\begin{pmatrix}v_1\\v_2\\v_3\end{pmatrix}=v_1\boldsymbol{i}+v_2\boldsymbol{j}+v_3\boldsymbol{k}$.	Components are with respect to the unit vectors $\boldsymbol{i}$, $\boldsymbol{j}$ and $\boldsymbol{k}$ (standard basis).	
	Algebraic and geometric approaches to the following:	Applications to simple geometric figures are essential.	
	• the sum and difference of two vectors; the zero vector, the vector $-\boldsymbol{v}$;	The difference of $\boldsymbol{v}$ and $\boldsymbol{w}$ is $\boldsymbol{v}-\boldsymbol{w}=\boldsymbol{v}+(-\boldsymbol{w})$. Vector sums and differences can be represented by the diagonals of a parallelogram.	
	• multiplication by a scalar, $k\boldsymbol{v}$; parallel vectors;	Multiplication by a scalar can be illustrated by enlargement.	
	• magnitude of a vector, $\lvert\boldsymbol{v}\rvert$;		
	• unit vectors; base vectors; $\boldsymbol{i}$, $\boldsymbol{j}$ and $\boldsymbol{k}$;		
	• position vectors $\overrightarrow{OA}=\boldsymbol{a}$;		
	• $\overrightarrow{AB}=\overrightarrow{OB}-\overrightarrow{OA}=\boldsymbol{b}-\boldsymbol{a}$.	Distance between points A and B is the magnitude of $\overrightarrow{AB}$.	

	Content	Further guidance	Links
4.2	The scalar product of two vectors. Perpendicular vectors; parallel vectors. The angle between two vectors.	The scalar product is also known as the "dot product". Link to 3.6, cosine rule. For non-zero vectors, $\boldsymbol{v} \cdot \boldsymbol{w} = 0$ is equivalent to the vectors being perpendicular. For parallel vectors, $\boldsymbol{w} = k\boldsymbol{v}$, $\lvert \boldsymbol{v} \cdot \boldsymbol{w} \rvert = \lvert \boldsymbol{v} \rvert \lvert \boldsymbol{w} \rvert$.	
4.3	Vector equation of a line in two and three dimensions: $\boldsymbol{r} = \boldsymbol{a} + t\boldsymbol{b}$. The angle between two lines.	Relevance of $\boldsymbol{a}$ (position) and $\boldsymbol{b}$ (direction). Interpretation of t as time and $\boldsymbol{b}$ as velocity, with $\lvert \boldsymbol{b} \rvert$ representing speed.	**Aim 8:** Vector theory is used for tracking displacement of objects, including for peaceful and harmful purposes. **TOK:** Are algebra and geometry two separate domains of knowledge? (Vector algebra is a good opportunity to discuss how geometrical properties are described and generalized by algebraic methods.)
4.4	Distinguishing between coincident and parallel lines. Finding the point of intersection of two lines. Determining whether two lines intersect.		

Topic 5—Statistics and probability 35 hours

The aim of this topic is to introduce basic concepts. It is expected that most of the calculations required will be done using technology, but explanations of calculations by hand may enhance understanding. The emphasis is on understanding and interpreting the results obtained, in context. Statistical tables will no longer be allowed in examinations. While many of the calculations required in examinations are estimates, it is likely that the command terms “write down”, “find” and “calculate” will be used.

	Content	Further guidance	Links
5.1	Concepts of population, sample, random sample, discrete and continuous data.	Continuous and discrete data.	**Appl:** Psychology: descriptive statistics, random sample (various places in the guide).
	Presentation of data: frequency distributions (tables); frequency histograms with equal class intervals;		**Aim 8:** Misleading statistics.
			Int: The St Petersburg paradox, Chebychev, Pavlovsky.
	box-and-whisker plots; outliers.	Outlier is defined as more than $1.5 \times \text{IQR}$ from the nearest quartile.	
		Technology may be used to produce histograms and box-and-whisker plots.	
	Grouped data: use of mid-interval values for calculations; interval width; upper and lower interval boundaries; modal class.		
	Not required: frequency density histograms.		

	Content	Further guidance	Links
5.2	Statistical measures and their interpretations. Central tendency: mean, median, mode. Quartiles, percentiles. Dispersion: range, interquartile range, variance, standard deviation. Effect of constant changes to the original data. Applications.	On examination papers, data will be treated as the population. Calculation of mean using formula and technology. Students should use mid-interval values to estimate the mean of grouped data. Calculation of standard deviation/variance using only technology. Link to 2.3, transformations. *Examples*: If 5 is subtracted from all the data items, then the mean is decreased by 5, but the standard deviation is unchanged. If all the data items are doubled, the median is doubled, but the variance is increased by a factor of 4.	**Appl:** Psychology: descriptive statistics (various places in the guide). **Appl:** Statistical calculations to show patterns and changes; geographic skills; statistical graphs. **Appl:** Biology 1.1.2 (calculating mean and standard deviation); Biology 1.1.4 (comparing means and spreads between two or more samples). **Int:** Discussion of the different formulae for variance. **TOK:** Do different measures of central tendency express different properties of the data? Are these measures invented or discovered? Could mathematics make alternative, equally true, formulae? What does this tell us about mathematical truths? **TOK:** How easy is it to lie with statistics?
5.3	Cumulative frequency; cumulative frequency graphs; use to find median, quartiles, percentiles.	Values of the median and quartiles produced by technology may be different from those obtained from a cumulative frequency graph.	

	Content	Further guidance	Links
5.4	Linear correlation of bivariate data. Pearson's product–moment correlation coefficient r. Scatter diagrams; lines of best fit. Equation of the regression line of y on x. Use of the equation for prediction purposes. Mathematical and contextual interpretation. **Not required:** the coefficient of determination R^2.	Independent variable x, dependent variable y. Technology should be used to calculate r. However, hand calculations of r may enhance understanding. Positive, zero, negative; strong, weak, no correlation. The line of best fit passes through the mean point. Technology should be used find the equation. Interpolation, extrapolation.	**Appl:** Chemistry 11.3.3 (curves of best fit). **Appl:** Geography (geographic skills). Measures of correlation; geographic skills. **Appl:** Biology 1.1.6 (correlation does not imply causation). **TOK:** Can we predict the value of x from y, using this equation? **TOK:** Can all data be modelled by a (known) mathematical function? Consider the reliability and validity of mathematical models in describing real-life phenomena.
5.5	Concepts of trial, outcome, equally likely outcomes, sample space (U) and event. The probability of an event A is $\mathrm{P}(A) = \frac{n(A)}{n(U)}$. The complementary events A and A' (not A). Use of Venn diagrams, tree diagrams and tables of outcomes.	The sample space can be represented diagrammatically in many ways. Experiments using coins, dice, cards and so on, can enhance understanding of the distinction between (experimental) relative frequency and (theoretical) probability. Simulations may be used to enhance this topic. Links to 5.1, frequency; 5.3, cumulative frequency.	**TOK:** To what extent does mathematics offer models of real life? Is there always a function to model data behaviour?

	Content	Further guidance	Links
5.6	Combined events, $\mathrm{P}(A \cup B)$. Mutually exclusive events: $\mathrm{P}(A \cap B) = 0$. Conditional probability; the definition $\mathrm{P}(A \mid B) = \dfrac{\mathrm{P}(A \cap B)}{\mathrm{P}(B)}$. Independent events; the definition $\mathrm{P}(A \mid B) = \mathrm{P}(A) = \mathrm{P}(A \mid B')$. Probabilities with and without replacement.	The non-exclusivity of "or". Problems are often best solved with the aid of a Venn diagram or tree diagram, without explicit use of formulae.	**Aim 8:** The gambling issue: use of probability in casinos. Could or should mathematics help increase incomes in gambling? **TOK:** Is mathematics useful to measure risks? **TOK:** Can gambling be considered as an application of mathematics? (This is a good opportunity to generate a debate on the nature, role and ethics of mathematics regarding its applications.)
5.7	Concept of discrete random variables and their probability distributions. Expected value (mean), $\mathrm{E}(X)$ for discrete data. Applications.	Simple examples only, such as: $\mathrm{P}(X = x) = \frac{1}{18}(4 + x)$ for $x \in \{1, 2, 3\}$; $\mathrm{P}(X = x) = \frac{5}{18}, \frac{6}{18}, \frac{7}{18}$. $\mathrm{E}(X) = 0$ indicates a fair game where X represents the gain of one of the players. Examples include games of chance.	

	Content	Further guidance	Links
5.8	Binomial distribution. Mean and variance of the binomial distribution. **Not required:** formal proof of mean and variance.	Link to 1.3, binomial theorem. Conditions under which random variables have this distribution. Technology is usually the best way of calculating binomial probabilities.	
5.9	Normal distributions and curves. Standardization of normal variables (z-values, z-scores). Properties of the normal distribution.	Probabilities and values of the variable must be found using technology. Link to 2.3, transformations. The standardized value (z) gives the number of standard deviations from the mean.	**Appl:** Biology 1.1.3 (links to normal distribution). **Appl:** Psychology: descriptive statistics (various places in the guide).

Topic 6—Calculus

40 hours

The aim of this topic is to introduce students to the basic concepts and techniques of differential and integral calculus and their applications.

	Content	Further guidance	Links
6.1	Informal ideas of limit and convergence.	*Example*: 0.3, 0.33, 0.333, ... converges to $\frac{1}{3}$. Technology should be used to explore ideas of limits, numerically and graphically.	**Appl:** Economics 1.5 (marginal cost, marginal revenue, marginal profit). **Appl:** Chemistry 11.3.4 (interpreting the gradient of a curve). **Aim 8:** The debate over whether Newton or Leibnitz discovered certain calculus concepts. **TOK:** What value does the knowledge of limits have? Is infinitesimal behaviour applicable to real life? **TOK:** Opportunities for discussing hypothesis formation and testing, and then the formal proof can be tackled by comparing certain cases, through an investigative approach.
	Limit notation.	*Example*: $\lim_{x\to\infty}\left(\frac{2x+3}{x-1}\right)$ Links to 1.1, infinite geometric series; 2.5–2.7, rational and exponential functions, and asymptotes.	
	Definition of derivative from first principles as $f'(x)=\lim_{h\to 0}\left(\frac{f(x+h)-f(x)}{h}\right)$.	Use of this definition for derivatives of simple polynomial functions only. Technology could be used to illustrate other derivatives. Link to 1.3, binomial theorem. Use of both forms of notation, $\frac{\mathrm{d}y}{\mathrm{d}x}$ and $f'(x)$, for the first derivative.	
	Derivative interpreted as gradient function and as rate of change.	Identifying intervals on which functions are increasing or decreasing.	
	Tangents and normals, and their equations. **Not required:** analytic methods of calculating limits.	Use of both analytic approaches and technology. Technology can be used to explore graphs and their derivatives.	

	Content	Further guidance	Links
6.2	Derivative of x^n $(n \in \mathbb{Q})$, $\sin x$, $\cos x$, $\tan x$, e^x and $\ln x$.		
	Differentiation of a sum and a real multiple of these functions.		
	The chain rule for composite functions.	Link to 2.1, composition of functions.	
	The product and quotient rules.	Technology may be used to investigate the chain rule.	
	The second derivative.	Use of both forms of notation, $\frac{d^2y}{dx^2}$ and $f''(x)$.	
	Extension to higher derivatives.	$\frac{d^ny}{dx^n}$ and $f^{(n)}(x)$.	

	Content	Further guidance	Links
6.3	Local maximum and minimum points. Testing for maximum or minimum.	Using change of sign of the first derivative and using sign of the second derivative. Use of the terms "concave-up" for $f''(x) > 0$, and "concave-down" for $f''(x) < 0$.	**Appl:** profit, area, volume.
	Points of inflexion with zero and non-zero gradients.	At a point of inflexion, $f''(x) = 0$ and changes sign (concavity change). $f''(x) = 0$ is not a sufficient condition for a point of inflexion: for example, $y = x^4$ at $(0,0)$.	
	Graphical behaviour of functions, including the relationship between the graphs of f, f' and f''. Optimization.	Both "global" (for large $\|x\|$) and "local" behaviour. Technology can display the graph of a derivative without explicitly finding an expression for the derivative. Use of the first or second derivative test to justify maximum and/or minimum values.	
	Applications. **Not required:** points of inflexion where $f''(x)$ is not defined: for example, $y = x^{1/3}$ at $(0,0)$.	Examples include profit, area, volume. Link to 2.2, graphing functions.	

	Content	Further guidance	Links
6.4	Indefinite integration as anti-differentiation.		
	Indefinite integral of x^n $(n \in \mathbb{Q})$, $\sin x$, $\cos x$, $\frac{1}{x}$ and e^x.	$\int \frac{1}{x} dx = \ln x + C$, $x > 0$.	
	The composites of any of these with the linear function $ax + b$.	*Example*: $f'(x) = \cos(2x+3) \Rightarrow f(x) = \frac{1}{2}\sin(2x+3) + C$.	
	Integration by inspection, or substitution of the form $\int f(g(x))g'(x)dx$.	*Examples*: $\int 2x(x^2+1)^4 dx$, $\int x \sin x^2 dx$, $\int \frac{\sin x}{\cos x} dx$.	
6.5	Anti-differentiation with a boundary condition to determine the constant term.	*Example*: if $\frac{dy}{dx} = 3x^2 + x$ and $y = 10$ when $x = 0$, then $y = x^3 + \frac{1}{2}x^2 + 10$.	**Int:** Successful calculation of the volume of the pyramidal frustum by ancient Egyptians (Egyptian Moscow papyrus). Use of infinitesimals by Greek geometers.
	Definite integrals, both analytically and using technology.	$\int_a^b g'(x)dx = g(b) - g(a)$. The value of some definite integrals can only be found using technology.	Accurate calculation of the volume of a cylinder by Chinese mathematician Liu Hui
	Areas under curves (between the curve and the x-axis). Areas between curves. Volumes of revolution about the x-axis.	Students are expected to first write a correct expression before calculating the area. Technology may be used to enhance understanding of area and volume.	**Int:** Ibn Al Haytham: first mathematician to calculate the integral of a function, in order to find the volume of a paraboloid.
6.6	Kinematic problems involving displacement s, velocity v and acceleration a.	$v = \frac{ds}{dt}$; $a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$.	**Appl:** Physics 2.1 (kinematics).
	Total distance travelled.	Total distance travelled $= \int_{t_1}^{t_2} \lvert v \rvert \, dt$.	

Assessment in the Diploma Programme

General

Assessment is an integral part of teaching and learning. The most important aims of assessment in the Diploma Programme are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessment are used in the Diploma Programme. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- Formative assessment informs both teaching and learning. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.
- Summative assessment gives an overview of previous learning and is concerned with measuring student achievement.

The Diploma Programme primarily focuses on summative assessment designed to record student achievement at or towards the end of the course of study. However, many of the assessment instruments can also be used formatively during the course of teaching and learning, and teachers are encouraged to do this. A comprehensive assessment plan is viewed as being integral with teaching, learning and course organization. For further information, see the IB *Programme standards and practices* document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the Diploma Programme, please refer to the publication *Diploma Programme assessment: Principles and practice*.

To support teachers in the planning, delivery and assessment of the Diploma Programme courses, a variety of resources can be found on the OCC or purchased from the IB store (http://store.ibo.org). Teacher support materials, subject reports, internal assessment guidance, grade descriptors, as well as resources from other teachers, can be found on the OCC. Specimen and past examination papers as well as markschemes can be purchased from the IB store.

Methods of assessment

The IB uses several methods to assess work produced by students.

Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do, and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses. Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

Markschemes

This generic term is used to describe analytic markschemes that are prepared for specific examination papers. Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from the students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response. A markscheme may include the content expected in the responses to questions or may be a series of marking notes giving guidance on how to apply criteria.

Assessment outline

First examinations 2014

Assessment component	Weighting
External assessment (3 hours)	**80%**
Paper 1 (1 hour 30 minutes) No calculator allowed. (90 marks) **Section A** Compulsory short-response questions based on the whole syllabus. **Section B** Compulsory extended-response questions based on the whole syllabus.	**40%**
Paper 2 (1 hour 30 minutes) Graphic display calculator required. (90 marks) **Section A** Compulsory short-response questions based on the whole syllabus. **Section B** Compulsory extended-response questions based on the whole syllabus.	**40%**
Internal assessment This component is internally assessed by the teacher and externally moderated by the IB at the end of the course. **Mathematical exploration** Internal assessment in mathematics SL is an individual exploration. This is a piece of written work that involves investigating an area of mathematics. (20 marks)	**20%**

External assessment

General

Markschemes are used to assess students in both papers. The markschemes are specific to each examination.

External assessment details

Paper 1 and paper 2

These papers are externally set and externally marked. Together, they contribute 80% of the final mark for the course. These papers are designed to allow students to demonstrate what they know and what they can do.

Calculators

Paper 1

Students are not permitted access to any calculator. Questions will mainly involve analytic approaches to solutions, rather than requiring the use of a GDC. The paper is not intended to require complicated calculations, with the potential for careless errors. However, questions will include some arithmetical manipulations when they are essential to the development of the question.

Paper 2

Students must have access to a GDC at all times. However, not all questions will necessarily require the use of the GDC. Regulations covering the types of GDC allowed are provided in the *Handbook of procedures for the Diploma Programme*.

Mathematics SL formula booklet

Each student must have access to a clean copy of the formula booklet during the examination. It is the responsibility of the school to download a copy from IBIS or the OCC and to ensure that there are sufficient copies available for all students.

Awarding of marks

Marks may be awarded for method, accuracy, answers and reasoning, including interpretation.

In paper 1 and paper 2, full marks are not necessarily awarded for a correct answer with no working. Answers must be supported by working and/or explanations (in the form of, for example, diagrams, graphs or calculations). Where an answer is incorrect, some marks may be given for correct method, provided this is shown by written working. All students should therefore be advised to show their working.

Paper 1

Duration: 1 hour 30 minutes

Weighting: 40%

- This paper consists of section A, short-response questions, and section B, extended-response questions.
- Students are not permitted access to any calculator on this paper.

Syllabus coverage

- Knowledge of **all** topics is required for this paper. However, not all topics are necessarily assessed in every examination session.

Mark allocation

- This paper is worth **90** marks, representing **40%** of the final mark.
- Questions of varying levels of difficulty and length are set. Therefore, individual questions may not necessarily each be worth the same number of marks. The exact number of marks allocated to each question is indicated at the start of the question.

Section A

This section consists of compulsory short-response questions based on the whole syllabus. It is worth approximately 45 marks.

The intention of this section is to test students' knowledge and understanding across the breadth of the syllabus. However, it should not be assumed that the separate topics are given equal emphasis.

Question type

- A small number of steps is needed to solve each question.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.

Section B

This section consists of a small number of compulsory extended-response questions based on the whole syllabus. It is worth approximately 45 marks. Individual questions may require knowledge of more than one topic.

The intention of this section is to test students' knowledge and understanding of the syllabus in depth. The range of syllabus topics tested in this section may be narrower than that tested in section A.

Question type

- Questions require extended responses involving sustained reasoning.
- Individual questions will develop a single theme.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.
- Normally, each question reflects an incline of difficulty, from relatively easy tasks at the start of a question to relatively difficult tasks at the end of a question. The emphasis is on problem-solving.

Paper 2

Duration: 1 hour 30 minutes

Weighting: 40%

This paper consists of section A, short-response questions, and section B, extended-response questions. A GDC is required for this paper, but not every question will necessarily require its use.

Syllabus coverage

- Knowledge of **all** topics is required for this paper. However, not all topics are necessarily assessed in every examination session.

Mark allocation

- This paper is worth **90** marks, representing **40%** of the final mark.
- Questions of varying levels of difficulty and length are set. Therefore, individual questions may not necessarily each be worth the same number of marks. The exact number of marks allocated to each question is indicated at the start of the question.

Section A

This section consists of compulsory short-response questions based on the whole syllabus. It is worth approximately 45 marks.

The intention of this section is to test students' knowledge and understanding across the breadth of the syllabus. However, it should not be assumed that the separate topics are given equal emphasis.

Question type

- A small number of steps is needed to solve each question.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.

Section B

This section consists of a small number of compulsory extended-response questions based on the whole syllabus. It is worth approximately 45 marks. Individual questions may require knowledge of more than one topic.

The intention of this section is to test students' knowledge and understanding of the syllabus in depth. The range of syllabus topics tested in this section may be narrower than that tested in section A.

Question type

- Questions require extended responses involving sustained reasoning.
- Individual questions will develop a single theme.
- Questions may be presented in the form of words, symbols, diagrams or tables, or combinations of these.
- Normally, each question reflects an incline of difficulty, from relatively easy tasks at the start of a question to relatively difficult tasks at the end of a question. The emphasis is on problem-solving.

Internal assessment

Purpose of internal assessment

Internal assessment is an integral part of the course and is compulsory for all students. It enables students to demonstrate the application of their skills and knowledge, and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught.

Internal assessment in mathematics SL is an individual exploration. This is a piece of written work that involves investigating an area of mathematics. It is marked according to five assessment criteria.

Guidance and authenticity

The exploration submitted for internal assessment must be the student's own work. However, it is not the intention that students should decide upon a title or topic and be left to work on the exploration without any further support from the teacher. The teacher should play an important role during both the planning stage and the period when the student is working on the exploration. It is the responsibility of the teacher to ensure that students are familiar with:

- the requirements of the type of work to be internally assessed
- the IB academic honesty policy available on the OCC
- the assessment criteria—students must understand that the work submitted for assessment must address these criteria effectively.

Teachers and students must discuss the exploration. Students should be encouraged to initiate discussions with the teacher to obtain advice and information, and students must not be penalized for seeking guidance. However, if a student could not have completed the exploration without substantial support from the teacher, this should be recorded on the appropriate form from the *Handbook of procedures for the Diploma Programme.*

It is the responsibility of teachers to ensure that all students understand the basic meaning and significance of concepts that relate to academic honesty, especially authenticity and intellectual property. Teachers must ensure that all student work for assessment is prepared according to the requirements and must explain clearly to students that the exploration must be entirely their own.

As part of the learning process, teachers can give advice to students on a **first draft** of the exploration. This advice should be in terms of the way the work could be improved, but this first draft must not be heavily annotated or edited by the teacher. The next version handed to the teacher after the first draft must be the final one.

All work submitted to the IB for moderation or assessment must be authenticated by a teacher, and must not include any known instances of suspected or confirmed malpractice. Each student must sign the coversheet for internal assessment to confirm that the work is his or her authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work to a teacher (or the coordinator) for internal assessment, together with the signed coversheet, it cannot be retracted.

Authenticity may be checked by discussion with the student on the content of the work, and scrutiny of one or more of the following:

- the student's initial proposal
- the first draft of the written work
- the references cited
- the style of writing compared with work known to be that of the student.

The requirement for teachers and students to sign the coversheet for internal assessment applies to the work of all students, not just the sample work that will be submitted to an examiner for the purpose of moderation. If the teacher and student sign a coversheet, but there is a comment to the effect that the work may not be authentic, the student will not be eligible for a mark in that component and no grade will be awarded. For further details refer to the IB publication *Academic honesty* and the relevant articles in the *General regulations: Diploma Programme*.

The same piece of work cannot be submitted to meet the requirements of both the internal assessment and the extended essay.

Group work

Group work should not be used for explorations. Each exploration is an individual piece of work.

It should be made clear to students that all work connected with the exploration, including the writing of the exploration, should be their own. It is therefore helpful if teachers try to encourage in students a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work.

Time allocation

Internal assessment is an integral part of the mathematics SL course, contributing 20% to the final assessment in the course. This weighting should be reflected in the time that is allocated to teaching the knowledge, skills and understanding required to undertake the work as well as the total time allocated to carry out the work.

It is expected that a total of approximately 10 teaching hours should be allocated to the work. This should include:

- time for the teacher to explain to students the requirements of the exploration
- class time for students to work on the exploration
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

Using assessment criteria for internal assessment

For internal assessment, a number of assessment criteria have been identified. Each assessment criterion has level descriptors describing specific levels of achievement together with an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Teachers must judge the internally assessed work against the criteria using the level descriptors.

- The aim is to find, for each criterion, the descriptor that conveys most accurately the level attained by the student.
- When assessing a student's work, teachers should read the level descriptors for each criterion, starting with level 0, until they reach a descriptor that describes a level of achievement that has not been reached. The level of achievement gained by the student is therefore the preceding one, and it is this that should be recorded.
- Only whole numbers should be recorded; partial marks, that is fractions and decimals, are not acceptable.
- Teachers should not think in terms of a pass or fail boundary, but should concentrate on identifying the appropriate descriptor for each assessment criterion.
- The highest level descriptors do not imply faultless performance but should be achievable by a student. Teachers should not hesitate to use the extremes if they are appropriate descriptions of the work being assessed.
- A student who attains a high level of achievement in relation to one criterion will not necessarily attain high levels of achievement in relation to the other criteria. Similarly, a student who attains a low level of achievement for one criterion will not necessarily attain low achievement levels for the other criteria. Teachers should not assume that the overall assessment of the students will produce any particular distribution of marks.
- It is expected that the assessment criteria be made available to students.

Internal assessment details

Mathematical exploration

Duration: 10 teaching hours

Weighting: 20%

Introduction

The internally assessed component in this course is a mathematical exploration. This is a short report written by the student based on a topic chosen by him or her, and it should focus on the mathematics of that particular area. The emphasis is on mathematical communication (including formulae, diagrams, graphs and so on), with accompanying commentary, good mathematical writing and thoughtful reflection. A student should develop his or her own focus, with the teacher providing feedback via, for example, discussion and interview. This will allow the students to develop area(s) of interest to them without a time constraint as in an examination, and allow all students to experience a feeling of success.

The final report should be approximately 6 to 12 pages long. It can be either word processed or handwritten. Students should be able to explain all stages of their work in such a way that demonstrates clear understanding. While there is no requirement that students present their work in class, it should be written in such a way that their peers would be able to follow it fairly easily. The report should include a detailed bibliography, and sources need to be referenced in line with the IB academic honesty policy. Direct quotes must be acknowledged.

The purpose of the exploration

The aims of the mathematics SL course are carried through into the objectives that are formally assessed as part of the course, through either written examination papers, or the exploration, or both. In addition to testing the objectives of the course, the exploration is intended to provide students with opportunities to increase their understanding of mathematical concepts and processes, and to develop a wider appreciation of mathematics. These are noted in the aims of the course, **in particular, aims 6–9 (applications, technology, moral, social**

and ethical implications, and the international dimension). It is intended that, by doing the exploration, students benefit from the mathematical activities undertaken and find them both stimulating and rewarding. It will enable students to acquire the attributes of the IB learner profile.

The specific purposes of the exploration are to:

- develop students' personal insight into the nature of mathematics and to develop their ability to ask their own questions about mathematics
- provide opportunities for students to complete a piece of mathematical work over an extended period of time
- enable students to experience the satisfaction of applying mathematical processes independently
- provide students with the opportunity to experience for themselves the beauty, power and usefulness of mathematics
- encourage students, where appropriate, to discover, use and appreciate the power of technology as a mathematical tool
- enable students to develop the qualities of patience and persistence, and to reflect on the significance of their work
- provide opportunities for students to show, with confidence, how they have developed mathematically.

Management of the exploration

Work for the exploration should be incorporated into the course so that students are given the opportunity to learn the skills needed. Time in class can therefore be used for general discussion of areas of study, as well as familiarizing students with the criteria.

Further details on the development of the exploration are included in the teacher support material.

Requirements and recommendations

Students can choose from a wide variety of activities, for example, modelling, investigations and applications of mathematics. To assist teachers and students in the choice of a topic, a list of stimuli is available in the teacher support material. However, students are not restricted to this list.

The exploration should not normally exceed 12 pages, including diagrams and graphs, but excluding the bibliography. However, it is the quality of the mathematical writing that is important, not the length.

The teacher is expected to give appropriate guidance at all stages of the exploration by, for example, directing students into more productive routes of inquiry, making suggestions for suitable sources of information, and providing advice on the content and clarity of the exploration in the writing-up stage.

Teachers are responsible for indicating to students the existence of errors but should not explicitly correct these errors. It must be emphasized that students are expected to consult the teacher throughout the process.

All students should be familiar with the requirements of the exploration and the criteria by which it is assessed. Students need to start planning their explorations as early as possible in the course. Deadlines should be firmly established. There should be a date for submission of the exploration topic and a brief outline description, a date for the submission of the first draft and, of course, a date for completion.

In developing their explorations, students should aim to make use of mathematics learned as part of the course. The mathematics used should be commensurate with the level of the course, that is, it should be similar to that suggested by the syllabus. It is not expected that students produce work that is outside the mathematics SL syllabus—however, this is not penalized.

Internal assessment criteria

The exploration is internally assessed by the teacher and externally moderated by the IB using assessment criteria that relate to the objectives for mathematics SL.

Each exploration is assessed against the following five criteria. The final mark for each exploration is the sum of the scores for each criterion. The maximum possible final mark is 20.

Students will not receive a grade for mathematics SL if they have not submitted an exploration.

Criterion A	Communication
Criterion B	Mathematical presentation
Criterion C	Personal engagement
Criterion D	Reflection
Criterion E	Use of mathematics

Criterion A: Communication

This criterion assesses the organization and coherence of the exploration. A well-organized exploration includes an introduction, has a rationale (which includes explaining why this topic was chosen), describes the aim of the exploration and has a conclusion. A coherent exploration is logically developed and easy to follow.

Graphs, tables and diagrams should accompany the work in the appropriate place and not be attached as appendices to the document.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	The exploration has some coherence.
2	The exploration has some coherence and shows some organization.
3	The exploration is coherent and well organized.
4	The exploration is coherent, well organized, concise and complete.

Criterion B: Mathematical presentation

This criterion assesses to what extent the student is able to:

- use appropriate mathematical language (notation, symbols, terminology)
- define key terms, where required
- use multiple forms of mathematical representation, such as formulae, diagrams, tables, charts, graphs and models, where appropriate.

Students are expected to use mathematical language when communicating mathematical ideas, reasoning and findings.

Students are encouraged to choose and use appropriate ICT tools such as graphic display calculators, screenshots, graphing, spreadsheets, databases, drawing and word-processing software, as appropriate, to enhance mathematical communication.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	There is some appropriate mathematical presentation.
2	The mathematical presentation is mostly appropriate.
3	The mathematical presentation is appropriate throughout.

Criterion C: Personal engagement

This criterion assesses the extent to which the student engages with the exploration and makes it their own. Personal engagement may be recognized in different attributes and skills. These include thinking independently and/or creatively, addressing personal interest and presenting mathematical ideas in their own way.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	There is evidence of limited or superficial personal engagement.
2	There is evidence of some personal engagement.
3	There is evidence of significant personal engagement.
4	There is abundant evidence of outstanding personal engagement.

Criterion D: Reflection

This criterion assesses how the student reviews, analyses and evaluates the exploration. Although reflection may be seen in the conclusion to the exploration, it may also be found throughout the exploration.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	There is evidence of limited or superficial reflection.
2	There is evidence of meaningful reflection.
3	There is substantial evidence of critical reflection.

Criterion E: Use of mathematics

This criterion assesses to what extent students use mathematics in the exploration.

Students are expected to produce work that is commensurate with the level of the course. The mathematics explored should either be part of the syllabus, or at a similar level or beyond. It should not be completely based on mathematics listed in the prior learning. If the level of mathematics is not commensurate with the level of the course, a maximum of two marks can be awarded for this criterion.

The mathematics can be regarded as correct even if there are occasional minor errors as long as they do not detract from the flow of the mathematics or lead to an unreasonable outcome.

Achievement level	Descriptor
0	The exploration does not reach the standard described by the descriptors below.
1	Some relevant mathematics is used.
2	Some relevant mathematics is used. Limited understanding is demonstrated.
3	Relevant mathematics commensurate with the level of the course is used. Limited understanding is demonstrated.
4	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is partially correct. Some knowledge and understanding are demonstrated.
5	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is mostly correct. Good knowledge and understanding are demonstrated.
6	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is correct. Thorough knowledge and understanding are demonstrated.

Glossary of command terms

Command terms with definitions

Students should be familiar with the following key terms and phrases used in examination questions, which are to be understood as described below. Although these terms will be used in examination questions, other terms may be used to direct students to present an argument in a specific way.

Calculate	Obtain a numerical answer showing the relevant stages in the working.
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of the similarities between two (or more) items or situations, referring to both (all) of them throughout.
Compare and contrast	Give an account of the similarities and differences between two (or more) items or situations, referring to both (all) of them throughout.
Construct	Display information in a diagrammatic or logical form.
Contrast	Give an account of the differences between two (or more) items or situations, referring to both (all) of them throughout.
Deduce	Reach a conclusion from the information given.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
Describe	Give a detailed account.
Determine	Obtain the only possible answer.
Differentiate	Obtain the derivative of a function.
Distinguish	Make clear the differences between two or more concepts or items.
Draw	Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.
Estimate	Obtain an approximate value.
Explain	Give a detailed account, including reasons or causes.
Find	Obtain an answer, showing relevant stages in the working.
Hence	Use the preceding work to obtain the required result.
Hence or otherwise	It is suggested that the preceding work is used, but other methods could also receive credit.
Identify	Provide an answer from a number of possibilities.

Integrate	Obtain the integral of a function.
Interpret	Use knowledge and understanding to recognize trends and draw conclusions from given information.
Investigate	Observe, study, or make a detailed and systematic examination, in order to establish facts and reach new conclusions.
Justify	Give valid reasons or evidence to support an answer or conclusion.
Label	Add labels to a diagram.
List	Give a sequence of brief answers with no explanation.
Plot	Mark the position of points on a diagram.
Predict	Give an expected result.
Show	Give the steps in a calculation or derivation.
Show that	Obtain the required result (possibly using information given) without the formality of proof. "Show that" questions do not generally require the use of a calculator.
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.
Solve	Obtain the answer(s) using algebraic and/or numerical and/or graphical methods.
State	Give a specific name, value or other brief answer without explanation or calculation.
Suggest	Propose a solution, hypothesis or other possible answer.
Verify	Provide evidence that validates the result.
Write down	Obtain the answer(s), usually by extracting information. Little or no calculation is required. Working does not need to be shown.

Notation list

Of the various notations in use, the IB has chosen to adopt a system of notation based on the recommendations of the International Organization for Standardization (ISO). This notation is used in the examination papers for this course without explanation. If forms of notation other than those listed in this guide are used on a particular examination paper, they are defined within the question in which they appear.

Because students are required to recognize, though not necessarily use, IB notation in examinations, it is recommended that teachers introduce students to this notation at the earliest opportunity. Students are **not** allowed access to information about this notation in the examinations.

Students must always use correct mathematical notation, not calculator notation.

$\mathbb{N}$	the set of positive integers and zero, $\{0, 1, 2, 3, ...\}$
$\mathbb{Z}$	the set of integers, $\{0, \pm 1, \pm 2, \pm 3, ...\}$
$\mathbb{Z}^+$	the set of positive integers, $\{1, 2, 3, ...\}$
$\mathbb{Q}$	the set of rational numbers
$^+$	the set of positive rational numbers, $\{x \mid x \in \quad, x > 0\}$
$\mathbb{R}$	the set of real numbers
$\mathbb{R}^+$	the set of positive real numbers, $\{x \mid x \in \quad, x > 0\}$
$\{x_1, x_2, ...\}$	the set with elements $x_1, x_2, ...$
$n(A)$	the number of elements in the finite set A
$\{x \mid \quad\}$	the set of all x such that
$\in$	is an element of
$\notin$	is not an element of
$\varnothing$	the empty (null) set
U	the universal set
$\cup$	Union

$\cap$	Intersection
$\subset$	is a proper subset of
$\subseteq$	is a subset of
A'	the complement of the set A
$a \mid b$	a divides b
$a^{1/n}$, $\sqrt[n]{a}$	a to the power of $\frac{1}{n}$, n^{th} root of a (if $a \geq 0$ then $\sqrt[n]{a} \geq 0$)
$\lvert x \rvert$	modulus or absolute value of x, that is $\begin{cases} x & \text{for } x \geq 0,\ x \in \\ -x & \text{for } x < 0,\ x \in \end{cases}$
$\approx$	is approximately equal to
$>$	is greater than
$\geq$	is greater than or equal to
$<$	is less than
$\leq$	is less than or equal to
$\ngtr$	is not greater than
$\nless$	is not less than
u_n	the n^{th} term of a sequence or series
d	the common difference of an arithmetic sequence
r	the common ratio of a geometric sequence
S_n	the sum of the first n terms of a sequence, $u_1 + u_2 + ... + u_n$
S_∞	the sum to infinity of a sequence, $u_1 + u_2 + ...$
$\sum_{i=1}^{n} u_i$	$u_1 + u_2 + ... + u_n$
$\binom{n}{r}$	the r^{th} binomial coefficient, $r = 0, 1, 2, \ldots$, in the expansion of $(a+b)^n$
$n!$	$n(n-1)(n-2) \times \quad \times 3 \times 2 \times 1$
$f : x \quad y$	f is a function under which x is mapped to y

$f(x)$	the image of x under the function f
f^{-1}	the inverse function of the function f
$f \quad g$	the composite function of f and g
$\lim\limits_{x \to a} f(x)$	the limit of $f(x)$ as x tends to a
$\dfrac{\mathrm{d}y}{\mathrm{d}x}$	the derivative of y with respect to x
$f'(x)$	the derivative of $f(x)$ with respect to x
$\dfrac{\mathrm{d}^2 y}{\mathrm{d}x^2}$	the second derivative of y with respect to x
$f''(x)$	the second derivative of $f(x)$ with respect to x
$\dfrac{\mathrm{d}^n y}{\mathrm{d}x^n}$	the n^{th} derivative of y with respect to x
$f^{(n)}(x)$	the n^{th} derivative of $f(x)$ with respect to x
$\int y \, \mathrm{d}x$	the indefinite integral of y with respect to x
$\int_a^b y \, \mathrm{d}x$	the definite integral of y with respect to x between the limits $x = a$ and $x = b$
e^x	exponential function (base e) of x
$\log_a x$	logarithm to the base a of x
$\ln x$	the natural logarithm of x, $\log_{\mathrm{e}} x$
sin, cos, tan	the circular functions
$\mathrm{A}(x, y)$	the point A in the plane with Cartesian coordinates x and y
[AB]	the line segment with end points A and B
AB	the length of [AB]
(AB)	the line containing points A and B
$\hat{A}$	the angle at A
$\mathrm{C\hat{A}B}$	the angle between [CA] and [AB]

ΔABC	the triangle whose vertices are A, B and C
$\boldsymbol{v}$	the vector $\boldsymbol{v}$
$\overrightarrow{\text{AB}}$	the vector represented in magnitude and direction by the directed line segment from A to B
$\boldsymbol{a}$	the position vector $\overrightarrow{\text{OA}}$
$\boldsymbol{i}, \boldsymbol{j}, \boldsymbol{k}$	unit vectors in the directions of the Cartesian coordinate axes
$\lvert\boldsymbol{a}\rvert$	the magnitude of $\boldsymbol{a}$
$\lvert\overrightarrow{\text{AB}}\rvert$	the magnitude of $\overrightarrow{\text{AB}}$
$\boldsymbol{v}\cdot\boldsymbol{w}$	the scalar product of $\boldsymbol{v}$ and $\boldsymbol{w}$
$\text{P}(A)$	probability of event A
$\text{P}(A')$	probability of the event “not A”
$\text{P}(A \mid B)$	probability of the event A given the event B
$x_1, x_2, \ldots$	Observations
$f_1, f_2, \ldots$	frequencies with which the observations $x_1, x_2, \ldots$ occur
$\begin{pmatrix} n \\ r \end{pmatrix}$	number of ways of selecting r items from n items
$\text{B}(n, p)$	binomial distribution with parameters n and p
$\text{N}(\mu, \sigma^2)$	normal distribution with mean μ and variance σ^2
$X \sim \text{B}(n, p)$	the random variable X has a binomial distribution with parameters n and p
$X \sim \text{N}(\mu, \sigma^2)$	the random variable X has a normal distribution with mean μ and variance σ^2
μ	population mean
σ^2	population variance
σ	population standard deviation
$\bar{x}$	mean of a set of data, $x_1, x_2, x_3, \ldots$

z	standardized normal random variable, $z = \dfrac{x - \mu}{\sigma}$
Φ	cumulative distribution function of the standardized normal variable with distribution $\mathrm{N}(0,\ 1)$
r	Pearson's product–moment correlation coefficient

C18-73 H

DELAWARE SCIENCE COALITION

Promoting Scientific Literacy for All Students

Delaware Science Coalition Memorandum of Agreement

The **Sussex Academy of Arts & Sciences** agrees to abide by the Delaware Science Coalition's bylaws and join the Delaware Science Coalition partnership. The Delaware Science Coalition program is sustained by local district/charter school fees in combination with state allocations. Professional development; materials acquisitions; distribution, collection and refurbishment of science curricular units; and any other associated costs are supported by these funding sources. The Coalition's bylaws and fee schedule for school year 2017-2018 are attached to this Memorandum of Agreement.

Signed:

SKaiser — 7/7/17

Director — **Date**

K12 Initiatives & Educator Engagement

CO MCB

7/7/17

Chief Academic Officer — **Date**

Teaching & Learning Branch

Karen Field Rogers — 7/24/17

Deputy Secretary of Education — **Date**

Patricia A. Oliphant — 8/3/17

LEA Official, Title — **Date**

MEMORANDUM OF UNDERSTANDING
THE SOCIAL STUDIES COALITION OF DELAWARE

PURPOSE OF THIS MEMO

This memorandum of understanding will define the roles and responsibilities of each party in the Social Studies Coalition of Delaware (SSCD). This Coalition is a partnership with the purpose to improve the teaching and learning of K-12 social studies in Delaware public schools and to help all Delaware public school students reach the Delaware Social Studies Standards.

The partnership includes the Department of Education, public school districts throughout the state, charter schools, and other agencies involved in standards-based instruction and assessment (Center for Economic Education and Entrepreneurship, Delaware Geography Alliance, Professional Development Center for Educators, Democracy Project and State Archives). The partnership is open to all public school entities, including vocational/technology schools and charter schools, that agree to collaborate in the systemic improvement of their K-12 social studies programs as outlined in this memorandum.

This Memorandum of Understanding (MoU) defines the conditions under which the Coalition will be financed, principles for operation and the collaborative processes as established by the Coalition. The MoU can be modified at any time by majority agreement of voting members of the Steering Committee.

MISSION

The Coalition exists to support the creation of the highest quality social studies instruction for the K-12 students in Delaware. The goals of the SSCD are to:

- Assist districts in the development of assessments to guide social studies curriculum development and instruction at the district level.
- Continue the development and alignment of social studies curriculum and instructional materials by designing model lessons and units for each benchmark to be distributed to members of the Coalition.
- Provide staff development for curriculum development, instructional delivery and assessment creation.
- Provide leadership and an organizational structure to facilitate planning, assist with the development of instructional materials and coordinate the delivery of the items listed above.

GUIDING PRINCIPLES

- The purpose of the partnership is to support continuous standards-based reform of social studies education in Delaware schools.
- Adoption and implementation of curricula is the responsibility of individual school systems. The Coalition is established to assist them in this endeavor and to provide cost effective standards-based education programs.
- Costs will be shared in a way that all parties benefit as equally as possible. Every effort will be made to provide services in support of the program at cost. Member districts and charter schools will pay **$2000** by Sept. 30, 2017 to support Coalition actions beginning July 1, 2017 through June 30, 2018 for professional development, development of products and other activities. Thereafter, annual fees will be determined by the Board.
- Professional development will be provided by the Coalition. Individual districts/charter schools will provide additional support for the participants.

- The Coalition will seek to coordinate financial support from foundations, affiliates and others for implementation of standards-based social studies education for Delaware students.

G0VERNANCE OF THE COALITION

The Coalition will be directed by the Board that includes voting and non-voting members. Voting members shall include a representative from each member school district and charter school that has paid its annual fee. Non-voting members shall include two representatives from the Department of Education, affiliate members including the Center for Economic Education and Entrepreneurship, the Delaware Geographic Alliance, the Professional Development Center for Educators, and the Delaware Public Archives.

The purpose of the Board is to:

- Establish and approve operating policies and practices for the Coalition.
- Set and approve the annual budget for the Coalition and monitor expenditures. The Milford School District has agreed to act as the fiscal agent at no cost, and for this will receive a reduced membership fee for the 2017-2018 school year.
- Establish and implement an effective communications program.
- Promote partnerships among the K-12 public schools, higher education and the business community.

Coalition Leadership –

SSCD leadership shall be administered by an Executive Committee and directed by the Board. The Executive Committee shall consist of two chairpersons, an Executive Secretary, a Financial Liaison and the Education Associate for Social Studies from the Delaware Department of Education. Two chairpersons shall be elected by the voting members of the Board to a two year, staggered term without remuneration and will coordinate the Coalition's activities and chair meetings. The Executive Secretary shall be appointed by the chairs. The Financial Liaison shall be appointed by the chairs.

Regular meetings of the Coalition's Executive Committee and Board will be held on a monthly basis during the school year. The Board will establish sub-committees to manage specific aspects of the Coalition as needed.

Signatures of Agreement – 2017 - 2018

Maureen McLaughlin   7/27/17

District/Charter Representative to SSCD   Date

Patricia A Oliphant   8/1/17

Superintendent –District /Charter   Date

School District/Charter School name Sussex Academy

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Geography **GRADE: 9**

Unit	Standards	Unit Concept /Essential Questions	Assessments
1- Course Introduction: Regional Planners Use Geographic Skills	Skills	Essential Questions: • Who plans for land use? Why are land use plans put into place? • What geographic principles and tools are used by planners in local communities?	Understanding the Geography Standards
2- Planners Solve Health Problems by Applying Geographic Principles	G1	• How is competition or interaction between places influenced by their relative location and accessibility? • How might the position of a place in a settlement hierarchy affect the life of the people in that place? • How can diffusion patterns be used to understand, manage and predict movement over time? Content Specific Vocabulary Geographic patterns, Emerge, Hierarchy, Accessibility, Diffusion, Complementarity	Formative: (Simulations/Activities) Analyzing Delaware's Emergency Services DE Health Initiative Delaware's Next Hospital Predicting the Spread of West Nile Virus Summative: (Project Presentation) Evaluating the Interstate Highway System
3- Planners Grapple with Environmental Issues	G2	Essential Questions: • How can the actions of humans impact the balance of physical systems? • How can governments around the world balance economic development and environmental concerns? Content Specific Vocabulary Physical environment, Interconnected- systems, Ecosystems, Scale	Formative: (Simulations/Activities) Natural Systems of Water and Air DGA Activity: Everglades Cancer and the Environment DGA Activity: San Andreas Fault Summative: (Project Presentation) Planning Alternative Energy Projects
4- Planning for Quality of Life	G3	Essential Questions: • How can individual citizens and citizen groups solve community environmental and social problems? Content Specific Vocabulary Geographic processes, Culture, Economic activity, Settlement	Formative: (Simulations/Activities) The Healthiest Places The Wealthiest Places Comfortable Places Time Changes Places Summative: (Project Presentation)

TEACHER'S NAME: Sara Messina **6/17**

			Citizens Evaluate Quality of Life in a Local Community
5- Spatial Analysis and Planning	G4	Essential Questions: • How can citizens affect comprehensive community planning decisions? Content Specific Vocabulary Boundaries, Complexity	Formative: (Simulations/Activities) Land Use Patterns and Plans Getting Care to Everyone: Planning a Network of Prenatal Centers Summative: (Project Presentation) Culminating Project Exposition- Describe the problem in geographic terms; Gather, organize and analyze data; Suggest a solution to the problem that is at least partly geographic.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: IB HL History **GRADE: 11/12**

Unit	Standards	Unit Concept /Essential Ideas	Assessments
Historiography	Syllabus and cross-curricular links are provided in the IB History Guide available on the International Baccalaureate Online Curriculum Center and attached as a PDF document.	Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary historiography, corroboration, point of view, source evaluation	Formative quizzes and summative tests are generated using the IB History Questionbank (a database of prior exam questions). Specimen Papers with example questions are available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Performance tasks are outlined in the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. These include applications and skills, international mindedness and theory of knowledge connections, as well as utilizations and aims of concepts.
20th Century Wars		Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary militarism, deterrence, industrialization, neomercantilist, alliance system, imperialism, nationalism, Weltpolitik, Balkans, Blank Cheque, Élan vitale, civil wars, anarcho-syndicalism, Comintern, Popular Front, rebels, loyalists, Neutrality Acts, pieds-noirs, Dien Bien Phu, Legionnaires, collective responsibility, Morice Line, decolonization, Evian Accords, partition, ceasefire, non-alignment, Mukti Bahni, junta, privatization, sovereignty	
The Second World War and the Americas, 1933-1945		Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary Smoot Hawley Tariff Act, abrogate, expropriation, legations, Pan-American Union, Grand Alliance, Anglo, GI Bill, Porfiriato	
The Cold War: Superpower Tensions and Rivalries		Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary proxy war, Lend Lease, Percentages Agreement, Atlantic Charter, Pearl Harbor, Manhattan Project,	

TEACHER'S NAME: Sara Messina **6/17**

		policy of containment, George Kennan, Marshall Plan, NATO, Pan-Arabism, Eisenhower Doctrine, revisionism, mutual assured destruction, deterrence, Domino Theory, hawks, doves, Cultural Revolution, détente, Ostpolitik, Brezhnev Doctrine, Russification, bourgeoisie, Manifest Destiny, Monroe Doctrine	
The Cold War and the Americas, 1945-1981		Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary containment, export-import, Dollar Diplomacy, Royal Canadian Mounted Police, Mattachine Society, Salami tactics, NSC-162/2, brinkmanship, plausible deniability, Domino Theory, Import Substitution Industrialization, agent orange	
Apartheid in South Africa, 1948-1964		Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary hunter-gatherer, pastoralist, cultivation, chiefdom, descendant, indigenous group, colony, free laborer, trekboer, covenant, indentured servant, capital, migrant labor, detained, scorched-earth campaign, guerilla tactics, concentration camp, treaty, self-governance, voting rights, unification, industry, strike, ethnic rivalry, armed resistance, mass mobilization, passbook, trade union, servile, boycott, civil disobedience, solidarity, separate development, homeland, pandering, multiracial, disillusioned, sabotage, embargo, diplomatic isolation, collaborator, entrenchment, emancipation, amnesty, reparation	
The Civil Rights Movement in the United States, 1954-1965		Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary	

		Ku Klux Klan, disenfranchisement, Brown v. Board of Education…(1954), Little Rock 1957, Jim Crow laws, Montgomery bus boycott 1955-56, Freedom Rides 1961, Freedom Summer 1964, Civil Rights Act 1964, Voting Rights Act 1965, Martin Luther King Jr., Malcolm X, Lyndon B. Johnson, NAACP, Southern Christian Leadership Conference, Student Non-Violent Coordinating Committee, Nation of Islam	
Civil Rights and Social Movements in the Americas post 1945		Concepts and Essential Ideas are outlined in detail throughout the IB History Guide available on the International Baccalaureate Online Curriculum Center and are attached as a PDF document. Content Specific Vocabulary First Nations, Seven Years War, land title, reserve, residential schools, patriate, Constitution Express, Nunavut, Idle No More, traditional tribal landholding, Alcatraz Island, preventative detention, Wounded Knee, mestizos, mulattoes, frontier justice, Niagra Movement, HBCUs, busing, Beloved Community, redlining, Mike Wallace, Bracero Program, Alianza Federal de Pueblos Libres, Rodolfo Gonzales, Proposition 187, baby boom, Julius and Ethel Rosenberg, hippies, counterculture, special relationship, New Left, Katimavik, Trudeaumania, Marshall McLuhan, The National Film Board of Canada, mutually assured destruction, Greenpeace, Pollution Probe, Royal Commission on the Status of Women in Canada, Red Power movement, Quiet Revolution	

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Social Studies **GRADE: 7**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Geo Review	Geography 1a RH.6-8.3 RH.6-8.4 RH.6-8.5 RH.6-8.7	Review of Geography 6 • What are themes of geography? • How do we read and use maps? Content Specific Vocabulary Hemisphere, latitude, longitude, parallels, meridians, physical, political, special purpose, scale, legend/key, orientation	INB check – formative Unit Test – summative Sample Question Determine the latitude and longitude coordinates using the provided map. Sample Project – formative Design or find illustrations to represent one of five themes of geography as specific to Delaware
Roman Republic	Civics 2 Civics 3 Geography 2a Geography 3a History 4b RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.6 RH.6-8.7 RH.6-8.8 RH.6-8.9	Roman Republic/Influence on Modern World • How did physical geography help Rome develop? • How are American and Roman government similar yet different? • How did Julius and Augustus Caesar change Rome? Bill of Rights/Civics • How does the Bill of Rights protect minority rights? • What other laws/policies protect minority rights in the US today? • How can citizens communicate with elected leaders? Content Specific Vocabulary Site, situation, cultural diffusion, patricians, plebeians, republic, Senate, veto, consul, dictator, primary source, secondary source, due process, rule of law	INB check – formative Unit Test – summative Sample Question Explain how the Bill of Rights protect minorities. Sample Performance Task Students compare Roman laws/12 Tables to Bill of Rights for protection of minority rights Sample Project – formative Create illustration that demonstrates Bill of Rights in real life scene/situation Project – formative

TEACHER'S NAME: BOWE/MCLAUGHLIN **6/17**

	RH.6-8.10		Students write argumentative response declaring Julius Caesar as either hero or villain Sample Performance Task Students write persuasive Letter to state rep about current issue (can be joint writing class project)
Roman Empire	Civics 1 Civics 3 Geography 2a Geography 3a Geography 3b History 4b RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.6 RH.6-8.7 RH.6-8.8 RH.6-8.9 RH.6-8.10	Roman Empire • How and where did the Roman Empire spread? • What caused the Empire to collapse? • How did the Romans influence the world today? Content Specific Vocabulary Pax Romano, martyr, cultural hearth, core, periphery, aqueduct, forum, inflation, mercenary	INB check – formative Unit Test – summative Sample Question Many factors – social, political economic –led to the end of the Roman Empire. Select ONE and justify why you think it had the greatest impact. Sample Performance Task Students research and write persuasive paragraph selecting best and worse Roman emperor using qualities/characteristics determined by group consensus* *Qualities of great/best to be used throughout year Sample Project – formative

			Students adopt perspective of Roman citizen writing a letter to their mother explaining why they have converted to Christianity
Arabia and Islam	Civics 1 Geography 1 Geography 3a Geography 3b History 4b RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7 RH.6-8.8 RH.6-8.10	Golden Age of Arabia and Rise of Islam • How did physical geography affect people of Arabian Peninsula? • How did trade lead to the spread of Islam? • How did the developments of the Golden Age influence the world today? Content Specific Vocabulary Plateau, oasis, wadi, Five Pillars, mosque, cultural hearth, core, periphery	INB check – formative Unit Test – summative Sample Question Explain the importance of trade in Arabia. Sample Project – formative Students research and write multi paragraph informative response about achievements and modern influences of Golden Age of Islam Sample Performance task – Students act as judge to select greatest* scientific achievement/invention of Golden Age of Islam
Castles and Crusades	Econ 3 History 4b RH.6-8.1	Medieval Europe and Crusades • How did collapse of Roman Empire affect medieval Europeans? • How did conflict in the Holy Land bring changes to Europe? • How did changes in economic systems affect medieval Europeans?	INB check – formative Unit Test – summative Sample Question Explain how guilds led to changes in

	RH.6-8.2 RH.6-8.4 RH.6-8.6 RH.6-8.7 RH.6-8.8 RH.6-8.9 RH.6-8.10	Content Specific Vocabulary Feudalism, manor, serf, Crusades, primary source, secondary source, medium of exchange, unit of account, store of value, guild market system, command system, traditional system	economic systems in medieval Europe. Sample Project – formative Students design a medieval castle (can be joint math project/geometry) Sample Performance Task Students complete document study then write Letter of/Not Recommendation for Salah al-Din Sample Project - formative Students write first person account of changing lifestyle of medieval manor vs. medieval town
Renaissance and Reformation: Beginning of a New World	Geo 1 History 4b RH.6-8.1 RH.6-8.2 RH.6-8.4 RH.6-8.6 RH.6-8.7 RH.6-8.9 RH.6-8.10	Renaissance and Reformation • What caused the Renaissance? • What role did humanism play in the development of new ideas? • What are the achievements and influences of the Renaissance and Reformation on the world today? Content Specific Vocabulary Humanism, patron, perspective, recant, indulgence, heliocentric, astrolabe, circumnavigate	INB check – formative Unit Test – summative Sample Question Explain the contributions of Galileo to modern science. Sample Project – summative Students create stained glass based on Learning Profile Thinkers to represent new ideas/thinkers of the Renaissance including written explanation

			Sample Performance Task – Based on study of Machiavelli, students analyze current event situation and make own decision/vote.
It's All About Choice	Econ1 Econ 2 Econ 3 RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7	Economics Review – Micro and Macro • How do supply and demand work? • What factors affect price? • What role do governments play in economics? • How do economic systems reflect the cultural values of a place? Content Specific Vocabulary Supply, demand, scarcity, surplus, price, production, consumer, producer, opportunity costs, competition, substitute goods, complimentary goods, productive resources, subsidies, market system, command system, traditional system	INB check – formative Unit Test – summative Sample Question High levels of rainfall damaged many pumpkins. Explain how this natural event may affect fruit pie sales. Sample Performance Task Students analyze sales data to make recommendations to business owner regarding sales/prices
A Bigger Picture	Econ 4 RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7 RH.6-8.8 RH.6-8.10	International Trade – Multinational Companies and Organizations • How has globalization changed national economies? • How have multinational companies impacted the US and world economies? Content Specific Vocabulary Specialization, tariff, quota, embargo, foreign, domestic, export, import, globalization, free trade, outsourcing, unemployment rate, Gross National Product	INB check – formative Unit Test – summative Sample Question Explain how a quota on Japanese cars would affect American consumers. Sample Project – formative Students track/map production of Nike shoe from natural resource to finished

			product Sample Performance Task – Students write argumentative letter to state legislators about impact of economic outsourcing on American labor market

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Social Studies **GRADE: 8**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Colonies to Country	Civics !b Civics 2b Econ 1a History 1a History 3a CC.8.5.6-8.A. CC.8.5.6-8.B. CC.8.5.6-8.F. CC.8.5.6-8.G. CC.8.5.6-8.H. . CC.8.6.6-8.B.	Developing Regions • Why do countries colonize? • How did geography impact the economy of the colonial regions? • How did the Atlantic Slave Trade evolve and impact global trade? Gaining Independence • What events and ideas led to American Revolution? • Why is the Declaration of Independence such a powerful document? • What effects did the Revolution have on the global economy? Foundations of our Government • What principles of the Constitution allow it to be a living document? • How does our system honor majority rule while protecting minority rights? Content Specific Vocabulary specialization, scarcity, mercantilism, popular sovereignty, propaganda, firebrand, federalism, checks and balances, capitalism, profiteer, contextualization, corroboration, eminent domain, due process	The Firebrands – Wanted Poster project - formative INB Checks - formative Causes of War Quiz - formative Unit Test – summative Formative Sample Question What evidence can you find in the graph above that would support Britain's need to establish a system of mercantilism? Summative Sample Performance Task Economics of Colonial Regions - Investment Simulation – students form investment companies and attempt to earn capital by investing in various products using geographic and cultural knowledge gained about each colonial region.
Expansion and Innovation	Hist 1a Hist 2a	Geographic Obstacles • What factors influenced western migration? • What geographic and economic obstacles did emigrants face?	Jackson's Indian Policy - debate - formative Achieving Our Destiny Prezi

TEACHER'S NAME: Janet Owens **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Social Studies **GRADE: 8**

	Hist 2b Hist 3b Econ 1a Econ 2a CC.8.6.6-8.H. CC.8.5.6-8.A. CC.8.5.6-8.I. CC.8.5.6-8.F. CC.8.6.6-8.G. CC.8.6.6-8.H.	Manifest Destiny and Political Sentiments • How and why did our country expand its borders? • How did our expansion impact other countries? Economic, Environmental, Social and Political Effects of Expansion • Why was this considered an economic boom? • How can the government impact the economy? • What groups were impacted most by our expansion? • How did our expansion lead to political dissention in Congress? Industrial Revolution • What advancements were made in the 1800's? • What impact did the Industrial Revolution have on Americans' daily lives? • Why were inventions made so rapidly during this time period? Content Vocabulary emigrant, inflation, opportunity cost, diplomacy, missionary, endemic, annex, cede, land grant, expansionists, canal system	Presentations - summative 1800's Economics Investment Game - formative INB Checks - formative Mapping Locations Quiz – formative Unit Test - summative Formative Sample Question Using the trail map provided, explain 3 dangers that an emigrant may encounter on this specific trail. Summative Sample Performance Task: Create an Emigrants Guide to advise travelers on how to survive the journey west in the 1800s.

TEACHER'S NAME: Janet Owens **6/17**

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COURSE: Social Studies **GRADE: 8**

Sectionalism and the Civil War	Civics 1a Civics 1b Civics 1c Hist 1a Hist 2a Hist 3a CC.8.5.6-8.A. CC.8.5.6-8.F. CC.8.5.6-8.G. CC.8.5.6-8.J.	Slavery, Sectionalism, and Civil War • How did the southern economy become so dependent on slavery? • What changes led to the growing differences between the northern and southern regions? • What conditions led to the growth of the Abolition Movement? Causes of Conflict • What political, economic, and social conditions led to the Civil War? • What actions were taken to avoid war? Industrial Age • How did the Industrial Revolution impact this war? (new technology, medical advancements) Content Vocabulary Sectionalism, platform, sovereignty, nullification, secession, anti-bellum, sharecropping, chattle, abolition, suffrage	*To Be A Slave* discussion questions – formative INB Checks - formative Causes of War Quiz– formative Unit Test – summative Formative Sample Question Create a CSET response to agree or disagree with this statement: "Without the invention of the cotton gin in 1793, the American Civil War would have never occurred."

TEACHER'S NAME: Janet Owens **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Social Studies **GRADE: 6**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Geo What?	Geography 1a RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7	**Introduction to Geography** • What are themes of geography? • How do we read and use maps? **Content Specific Vocabulary** Hemisphere, latitude, longitude, parallels, meridians, physical, political, special purpose, scale, legend/key, orientation	INB check – formative Unit Test – summative Sample Question Determine the latitude and longitude coordinates using the provided map. Sample Project – formative Design or find illustrations to represent one of five themes of geography
Examining the Earth	Geography 2a RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7	**Physical Geography** • What physical phenomena exist in our world? • How do people adapt and respond to physical geography? • How did physical geography affect the world and me? • Why are natural resources important? **Content Specific Vocabulary** Orbit, axis, rotation, revolution, solstice, equinox, tropic lines, landform, plateau, climate, precipitation, deciduous, coniferous, tundra, adaptation, raw material, renewable resource, non renewable resource, fossil fuel	INB check – formative Unit Test – summative Sample Question Explain which climate zone is represented on the provided climate graph. Use evidence from the graph to support your claim. Sample Performance Task Students travel to a different climate zone and explain adaptations to food, clothing and activities in the new environment
Small World	Geography 3 RH.6-8.2	**Human Geography** • What affects population? • Where and why do people move?	INB check – formative Unit Test – summative

	RH.6-8.3 RH.6-8.4 RH.6-8.7	• What is culture and how can we study it? • How does culture change over time? • How can I develop a respect for all cultures? **Content Specific Vocabulary** Population, population density, birthrate, death rate, life expectancy, migration, push/pull factors, urbanization, culture, cultural traits, technology, social structure, nuclear family, extended family, matriarchal, patriarchal, cultural diffusion, acculturation, global village	Sample Question Write a paragraph response explaining how culture can change over time. Provide specific examples to support your claim. Sample Performance Task Students acts as geographers and analyze own family for cultural traits OR analyze cultural traits of American culture
Prehistory	History 4b RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7	**Early People/Rise of Civilization** • How do we date human events? • What was life like for early humans? • What are the components of civilization? **Content Specific Vocabulary** Prehistory, history, archaeologist, Paleolithic, Neolithic, nomad, agriculture, artisan, social class, surplus, civilization	INB check – formative Unit Test – summative Sample Question Based on the video clip, explain two inaccuracies about Paleolithic life demonstrated in the film. Sample Project – formative Research and create one paragraph informative response about Neolithic life (Skara Brae, Catal Hoyuk)
Mesopotamia and Canaan	Civics 1 Geography 1 Geography 3a	**Early Civilizations** • How did physical geography affect these people? • What is purpose and form of government? • How did these people influence the world today?	INB check – formative Unit Test – summative Sample Question:

	Geography 3b History 4b RH.6-8.1 RH.6-8.2 RH.6-8.4 RH.6-8.7	**Content Specific Vocabulary** Site, situation, polytheism, monotheism, government, monarchy, constitution, foreign policy, cuneiform, innovation, cultural hearth, tolerance, Torah, 10 Commandments	Select one purpose of government and explain an ancient and modern example. Performance Task Students craft poem recognizing influences of Mesopotamia on modern world Sample Project – formative Students write one paragraph informative letter about Judaism and importance of respecting culture
Egypt	Civics 1 Geography 1 Geography 3a Geography 3b History 4b RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7 RH.6-8.8	**Great Civilizations/Affects of Physical Geography** • How did physical geography affect the growth of Egypt? • What are the purposes and affects of dams? • How are historical documents/artifacts categorized? • What is unique about Egyptian culture? **Content Specific Vocabulary** Cataract, delta, silt, inundation, source, mouth, topography, reservoir, pharaoh, dynasty, primary source, secondary source, hieroglyphics, papyrus, myth	INB check – formative Unit Test – summative Sample Question Explain if Source A is a primary or secondary source. Use evidence from the document to support your claim. Project – formative Students write one paragraph informative response about the affects of the Nile and affects on humans on the Nile Project – formative

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Social Studies **GRADE: 6**

			Students design personalized scale drawing sarcophagus/mummy coffin (can be joint math project)
Greece	Civics 1 Econ 3 Geography 1 Geography 3a Geography 3b Geography 4 History 4b RH.6-8.1 RH.6-8.2 RH.6-8.3 RH.6-8.4 RH.6-8.7	**Great Civilizations/Influences on Modern World** • How did physical geography affect the development of Greek city-states? • What types of government existed in Ancient Greece? • How did economics influence Greek culture? • How did cooperation and conflict led to decline of Ancient Greece? • How did the Greeks influence the world today? **Content Specific Vocabulary** Peninsula, city-state, colony, specialization, aristocracy, direct democracy, representative democracy, tyrant, scarcity, human resources, capital resources, market, command, traditional, opportunity cost	INB check – formative Unit Test – summative Sample Question Explain how physical geography led to the formation of Greek city-states. Sample Performance Task Students research and write argumentative one paragraph nominating one of 12 Greeks to become member of Greatest Greeks Hall of Fame

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Reading and Literature **GRADE: 7**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Revisiting the CSET Response Strategy	CCSS.ELA-Literacy.RI.7.1 CCSS.ELA-Literacy.RI.7.6 CCSS.ELA-Literacy.RL.7.10 CCSS.ELA-Literacy.RI.7-10	**Review of CSET** • What are the components of the CSET response strategy? • How do we write CSET's? **Content Specific Vocabulary** Establish a claim, evidence, cite, quote, argument, source, specific & relevant supporting details, elaboration, infer, inference, justify, key details, paraphrasing, organization, purpose, transitions, conclude, conclusion, context, background knowledge, plagiarism	CSET: Identify and support the narrative perspective of the book you are reading independently. Use the CSET writing strategy – formative Sample Question: CSET :Should we have zoos or should zoos be closed? – summative Performance Task – Students wrote an argumentative essay after conducting research and fieldwork arguing for or against zoos. Project – Using the CSET response strategy that identifies a scene in which a character from a summer reading book exemplified one of the Learner Profile Attributes. Write the scene in first person as the character and Illustrate the character using text details.
Proverbs	CCSS.ELA-Literacy.RL.7.4 CCSS.ELA-	**Proverbs** • What are proverbs? • What are the purpose of proverbs?	Proverbs Homework: define and create a real life examples– formative

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Reading and Literature **GRADE: 7**

	Literacy.RL.7.10 CCSS.ELA-Literacy.RL. 7.1	• What does the proverb mean? • How do proverbs relate to my life? **Content Specific Vocabulary** Connotation, denotation, allusion, metaphor, definition, illustrate, relationship, synonym, antonym, tone, mental picture/image, personification, context, literal meaning versus figurative meaning	Proverb Quizzes – summative Sample Question: Jonah wanted to have a career as a pilot. He was unsure if he should join the Air Force, Major in aviation in college, or attend flight school in order to learn the skills. Which proverb does this example exemplify? Project – formative Students reflected on the proverbs they learned over the year and related to the IB Learner Profile Traits. Students illustrated the literal and figurative meanings of the proverb.
Reading Logs	CCSS.ELA-Literacy.RL.7.2 CCSS.ELA-Literacy.RL.7.3 CCSS.ELA-Literacy.RL.7.4 CCSS.ELA-Literacy.RL.7.6	**Reading Logs – Reading Response to Independent Reading** • What are the elements of literature? • How are the elements of literature used in my independent reading? • What is summarization? **Content Specific Vocabulary** Character traits, round/flat characters, static/dynamic characters, protagonist/antagonists, character foil, internal/external conflict, conflict (man vs. …), initiating conflict, plot, setting, main/minor characters, point-of-view (1st,2ns, 3rd limited, 3rd omniscient, 3rd objective), exposition, rising action,	Reading logs – formative Sample Question: Provide a literary definition for point-of-view. What is the difference between limited, omniscient and objective point-of-view? Identify the point-of-view in your book. Provide a cite from the text that supports the point-of-view you chose.

	CCSS.ELA-Literacy.RL.7.10 CCSS.ELA-	climax/turning point, falling action, dénouement, plot, theme, dialogue, similes, metaphors, imagery, idioms, hyperbole, evidence, summarization, key points, logical sequence of events, mood, tone, flashback, foreshadowing	
Informational Text	CCSS.ELA-Literacy.RI.7.1 CCSS.ELA-Literacy.RI.7.2 CCSS.ELA-Literacy.RI.7.3 CCSS.ELA-Literacy. RI.7.4 CCSS.ELA-Literacy.RI.7.5 CCSS.ELA-Literacy.RI.7.6 CCSS.ELA-Literacy.RI.7.7 CCSS.ELA-Literacy.RI.7.8 CCSS.ELA-Literacy.RI.7.9 CCSS.ELA-Literacy.RI.7.10	**Elements of Nonfiction** • How does a reader effectively annotate a text to increase comprehension? • How does a reader identify the structure of a text? • How does a reader identify the key details of a text and use them effectively in writing responses? • How does a reader use context clues to deal with difficult vocabulary? **Content Specific Vocabulary** Accurate/inaccurate information, viewpoint, tone, claims, analysis, argument. Audience, author's intent/message/purpose, central idea, text structure (compare/contrast, cause/effect, chronological/sequence, problem/solution/pro/con, description), evidence, text features (bold, italics, charts, tables, diagrams, lists, text boxes, images), annotation, attention getting leads, rhetorical questions, paraphrasing, plagiarism, point-of-view, word choice, denotation, connotation, bias, reference/source, summarize, transitions, voice, trustworthy sources, websites, primary/secondary sources	Homework, classwork,– formative Quizzes, CSET's – summative Sample Question: How did the editors of the video capture the attention of the viewer? Locate a cite from the passage the best illustrates how the author, Captain John Smith, organized information in his account. Identify one piece of evidence that both authors use. How do they use it differently? Support your answer with details from the editorials. Performance task – Students write as Martin Luther King, using an excerpt from "Letter from Birmingham Jail", a response to Jackie Robinson's letter to President Eisenhower regarding the lack of civil rights and equality for African Americans.

			Performance Task: Students compared a video and text of a scientific research study and the differences in evidence, tone, and purpose. – summative
Poetry	CCSS.ELA-Literacy.RL.7.1 CCSS.ELA-Literacy. RL.7.2 CCSS.ELA-Literacy. RL.7.3 CCSS.ELA-Literacy. RL.7.4 CCSS.ELA-Literacy. RL.7.5 CCSS.ELA-Literacy. RL.7.6 CCSS.ELA-Literacy. RL.7.7 CCSS.ELA-Literacy. RL.7.9 CCSS.ELA-Literacy. RL.7.10	**Poetry: Interpretation and Construction** • What are the elements of poetry? • How are literary devices used to enhance poetry and its meaning? • How does a reader analyze a poem for understanding and meaning? **Content Specific Vocabulary** Genre: lyric, narrative, dramatic. Form: stanza, line, quatrain, free verse, blank verse, haiku, .Figurative language: hyperbole, irony, metaphor, extended metaphor, oxymoron, onomatopoeia, paradox, personification, imagery, symbol, allusion. Sound devices: rhyme scheme, alliteration, assonance, consonance, rhythm, refrain, repetition, meter, feet, mood, tone, theme, portmanteau, stressed/unstressed syllables, context	Homework, classwork, – formative Unit Test – summative Sample Question: Identify the theme of the poem "Hope" is the thing with feathers (314) by Emily Dickinson. Support your answers with details from the poem. Performance Task: Students compared an initial reading and analysis of "Dreams" by Langston Hughes to another analysis with the historical context of Hughes and the Harlem Rennaissance. Students then continued the comparison of the same poem to a Nike Ad that used it for an Olympic ad campaign focusing on Sandra Richards-Ross. Project - formative Students write first person account of changing lifestyle of medieval manor vs.

			medieval town
Drama	CCSS.ELA-Literacy.RL.7.1 CCSS.ELA-Literacy.RL.7.2 CCSS.ELA-Literacy.RL.7.3 CCSS.ELA-Literacy. RL.7.4 CCSS.ELA-Literacy.RL.7.5 CCSS.ELA-Literacy.RL.7.6 CCSS.ELA-Literacy.RL.7.7 CCSS.ELA-Literacy.RL.7.9 CCSS.ELA-Literacy.RL.7.10	**Drama** • What is drama and what literary elements are utilized in drama? • How does drama differ from other literary genres? • How does drama provide the reader a different experience that prose or poetry? **Content Specific Vocabulary** Playwright, director, characterization, tragedy, comedy, antagonist, protagonist, soliloquy, monologue, dialogue, stage directions, props, set, exposition,	Classwork, homework – formative Unit Test – summative Sample Question: Read the following claim: Young Lady did not think highly of the Dentist. Find two cites from the stage directions and two cites from the dialogue that support the claim. Performance Task – Students wrote an additional scene on to the end of the play in the style and format of drama.
Tangerine and The Outsiders	CCSS.ELA-Literacy.RL.7.1 CCSS.ELA-Literacy.RL.7.2 CCSS.ELA-Literacy.	**Novel Studies: The Elements of Realistic Fiction** • How does the development and use of literary elements convey meaning? • How does active reading enhance understanding? • What is the importance of understanding vocabulary to gain meaning from the text? • How is theme connected to character, conflict and the reader? • How does the point of view impact a piece of literature?	Classwork, homework, reading checks – formative CSET – summative Sample Question: In the end of Part 2, Paul says to his

	RL.7.3 CCSS.ELA-Literacy. RL.7.4 CCSS.ELA-Literacy. RL.7.6 CCSS.ELA-Literacy. RL.7.7 CCSS.ELA-Literacy. RL.7.9 CCSS.ELA-Literacy. RL.7.10	• How does knowledge about an author's personal experiences impact the reading and interpretation of their work? **Content Specific Vocabulary** Mood, setting, irony, conflict, foreshadowing, suspense, symbolism, flashback, characterization, point of view, theme, exposition, rising action, climax, falling action, denouement, plot structure, genres	mother "It was quite a ride." This statement means one thing on the surface, but holds a deeper meaning underneath. What is the literal interpretation of his words and what is the hidden meaning of his words. Support your answer with details from the text Performance Task Students created a wanted poster for a character using details from the text from the perspective of an outside character

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Reading **GRADE: 7**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Revisiting the CSET Response Strategy	RI.7.1 RI.7.6 RL.7.10 RI.7-10	**Review of CSET** • What are the components of the CSET response strategy? • How do we write CSET's? **Content Specific Vocabulary** Establish a claim, evidence, cite, quote, argument, source, specific & relevant supporting details, elaboration, infer, inference, justify, key details, paraphrasing, organization, purpose, transitions, conclude, conclusion, context, background knowledge, plagiarism	CSET: Identify and support the narrative perspective of the book you are reading independently. Use the CSET writing strategy – formative Summative Sample Question CSET: Should we have zoos or should zoos be closed? Performance Task Students write an argumentative essay after conducting research and fieldwork arguing for or against zoos. Summative Sample Project Using the CSET response strategy that identifies a scene in which a character from a summer reading book exemplified one of the Learner Profile Attributes. Write the scene in first person as the character and Illustrate the character using text details.
Proverbs	RL.7.4 RL.7.10 RL. 7.1	**Proverbs** • What are proverbs? • What is the purpose of proverbs?	Proverbs Homework Define and create real life examples–formative

TEACHER'S NAME: Foley 6/17

		• What does the proverb mean? • How do proverbs relate to my life? **Content Specific Vocabulary** Connotation, denotation, allusion, metaphor, definition, illustrate, relationship, synonym, antonym, tone, mental picture/image, personification, context, literal meaning versus figurative meaning	Proverb Quizzes Summative Sample Question Jonah wanted to have a career as a pilot. He was unsure if he should join the Air Force, major in aviation in college, or attend flight school in order to learn the skills. Which proverb does this example exemplify? Formative Sample Project Students reflected on the proverbs they learned over the year and related to the IB Learner Profile Traits. Students illustrated the literal and figurative meanings of the proverb.
Reading Logs	RL.7.2 RL.7.3 RL.7.4 RL.7.6 RL.7.10	**Reading Logs – Reading Response to Independent Reading** • What are the elements of literature? • How are the elements of literature used in my independent reading? • What is summarization? **Content Specific Vocabulary** Character traits, round/flat characters, static/dynamic characters, protagonist/antagonists, character foil, internal/external conflict, conflict (man vs. …), initiating conflict, plot, setting, main/minor characters, point-of-view (1st, 2nd, 3rd limited, 3rd omniscient, 3rd objective), exposition, rising action, climax/turning point, falling action, dénouement, plot, theme, dialogue, similes, metaphors, imagery,	Reading logs – formative Sample Question Provide a literary definition for point-of-view. What is the difference between limited, omniscient and objective point-of-view? Identify the point-of-view in your book. Provide and cite from the text that supports the point-of-view you chose.

		idioms, hyperbole, evidence, summarization, key points, logical sequence of events, mood, tone, flashback, foreshadowing	
Informational Text	RI.7.1 RI.7.2 RI.7.3 RI.7.4 RI.7.5 RI.7.6 RI.7.7 RI.7.8 RI.7.9 RI.7.10	**Elements of Nonfiction** • How does a reader effectively annotate a text to increase comprehension? • How does a reader identify the structure of a text? • How does a reader identify the key details of a text and use them effectively in writing responses? • How does a reader use context clues to deal with difficult vocabulary? **Content Specific Vocabulary** Accurate/inaccurate information, viewpoint, tone, claims, analysis, argument, audience, author's intent/message/purpose, central idea, text structure (compare/contrast, cause/effect, chronological/sequence, problem/solution/pro/con, description), evidence, text features (bold, italics, charts, tables, diagrams, lists, text boxes, images), annotation, attention getting leads, rhetorical questions, paraphrasing, plagiarism, point-of-view, word choice, denotation, connotation, bias, reference/source, summarize, transitions, voice, trustworthy sources, websites, primary/secondary sources	Homework, classwork,– formative Quizzes, CSET's – Summative Sample Question How did the editors of the video capture the attention of the viewer? Locate and cite from the passage the example that best illustrates how the author, Captain John Smith, organized information in his account. Identify one piece of evidence that both authors use. How do they use it differently? Support your answer with details from the editorials. Sample Performance Task Students write as Martin Luther King, using an excerpt from "Letter from Birmingham Jail", a response to Jackie Robinson's letter to President Eisenhower regarding the lack of civil rights and equality for African Americans.

			Sample Performance Task Students compare a video and text of a scientific research study and the differences in evidence, tone, and purpose. – summative
Poetry	RL.7.1 RL.7.2 RL.7.3 RL.7.4 RL.7.5 RL.7.6 RL.7.7 RL.7.9 RL.7.10	**Poetry: Interpretation and Construction** • What are the elements of poetry? • How are literary devices used to enhance poetry and its meaning? • How does a reader analyze a poem for understanding and meaning? **Content Specific Vocabulary** Genre: lyric, narrative, dramatic. Form: stanza, line, quatrain, free verse, blank verse, haiku. Figurative language: hyperbole, irony, metaphor, extended metaphor, oxymoron, onomatopoeia, paradox, personification, imagery, symbol, allusion. Sound devices: rhyme scheme, alliteration, assonance, consonance, rhythm, refrain, repetition, meter, feet, mood, tone, theme, portmanteau, stressed/unstressed syllables, context	Homework, classwork, – formative Unit Test – summative Sample Question: Identify the theme of the poem "'Hope' is the thing with feathers" (314) by Emily Dickinson. Support your answers with details from the poem. Sample Performance Task Students compare an initial reading and analysis of "Dreams" by Langston Hughes to another analysis with the historical context of Hughes and the Harlem Renaissance. Students then continued the comparison of the same poem to a Nike Ad that used it for an Olympic ad campaign focusing on Sandra Richards-Ross. Sample Project - formative

			Students write first person account of changing lifestyle of medieval manor vs. medieval town
Drama	RL.7.1 RL.7.2 RL.7.3 RL.7.4 RL.7.5 RL.7.6 RL.7.7 RL.7.9 RL.7.10	**Drama** • What is drama and what literary elements are utilized in drama? • How does drama differ from other literary genres? • How does drama provide the reader a different experience that prose or poetry? **Content Specific Vocabulary** Playwright, director, characterization, tragedy, comedy, antagonist, protagonist, soliloquy, monologue, dialogue, stage directions, props, set, exposition,	Classwork, homework – formative Unit Test – summative Sample Question: Read the following claim: Young Lady did not think highly of the Dentist. Find two cites from the stage directions and two cites from the dialogue that support the claim. Sample Performance Task Students wrote an additional scene on to the end of the play in the style and format of drama.
Tangerine and The Outsiders	RL.7.1 RL.7.2 RL.7.3 RL.7.4 RL.7.6 RL.7.7 RL.7.9 RL.7.10	**Novel Studies: The Elements of Realistic Fiction** • How does the development and use of literary elements convey meaning? • How does active reading enhance understanding? • What is the importance of understanding vocabulary to gain meaning from the text? • How is theme connected to character, conflict and the reader? • How does the point of view impact a piece of literature? • How does knowledge about an author's personal experiences impact the reading and interpretation of their work? **Content Specific Vocabulary** Mood, setting, irony, conflict, foreshadowing, suspense, symbolism, flashback, characterization, point	Classwork, homework, reading checks – formative CSET – Summative Sample Question: In the end of Part 2, Paul says to his mother "It was quite a ride." This statement means one thing on the surface, but holds a deeper meaning underneath. What is the literal interpretation of his words and what is the hidden meaning of his words.

		of view, theme, exposition, rising action, climax, falling action, denouement, plot structure, genres	Support your answer with details from the text. Sample Performance Task Students create a wanted poster for a character using details from the text from the perspective of an outside character

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Writing **GRADE: 8**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Narrative Writing	W.8.3, W.8.4, W.8.5, W.8.8, W.8.10 L.8.5 SL.8.1	**Key Concept** Write narrative essays to develop real experiences using relevant descriptive details and well-structured pacing. **Essential Questions** • How can I write an effective personal narrative essay with relevant, descriptive details? • How can I use narrative techniques such as dialogue, pacing, and figurative language to enhance my narrative piece? • How can I use the writing process to improve my writing and communication skills? • How can I use narrative techniques such as dialogue, pacing, description and reflection to develop an experience, event or character? • How can I use precise words and phrases, relevant descriptive details, and sensory language to capture the action and convey experiences and events? • How can I write a conclusion that follows from and reflects on the narrated experiences or events? **Content Specific Language** Figurative language, narrative elements, point of view, brainstorming, revising, drafting, proofreading, ideas, organization, word choice, voice, conventions, sentence fluency	Formative Assessments • Paragraph writing exercises • Exit tickets • Individual conferences with students during the writing process • Feedback on organizers and rough drafts Formative Assessment Sample • Write a paragraph that uses dialogue to indirectly characterize the speaker or situation. Summative Assessment Sample • Write a full personal narrative essay that has been put through the entire writing process and incorporates the 6 Traits.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Writing **GRADE: 8**

Informative Writing	SL.8.2, 8.4, 8.5, 8.6, W.8.2, 8.4, 8.5, 8.7,.8.8, 8.10	**Key Concept** Examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. **Essential Questions** • How can I write an informative/explanatory text with relevant well-chosen facts to fully explain a topic? • How can I conduct research and support my thesis to prove what I think is the most important technological device of our time? • How can I write an engaging lead and first section that orients the reader and provides an introduction to the topic? • How do I use quotes from experts (written texts, speeches or interviews)? • How do I demonstrate understanding of a topic through full development including, facts, statistics, examples, anecdotes, and quotations? **Content Specific Language:** Evidence, Explanation, Transition, Paragraphing, Introduction topic sentence	Formative Assessments • Paragraph writing focusing on text based writing • Daily proofreading exercises • Using rubrics, checklists, feedback and conference notes Formative Assessment Sample • Write an informative paragraph about the topic of your choice. Summative Assessment Sample • Write a full informative essay that has been put through the writing process and incorporates the 6 Traits.
Argumentative Writing		**Key Concept** Write arguments to support claims with clear reasons, relevant evidence and inclusion of counterclaim and refutation.	Formative Assessments • Analysis of example letter to

		Essential Questions • How can I demonstrate an understanding of logical argument structure and effective rhetorical approaches to forming an argument? • How can I compose a coherent argument essay with clear reasons and relevant evidence to support my claims? • How can I skillfully acknowledge and distinguish the claims from alternate or opposing counterclaims? **Content Specific Language** CSET, Counterclaim, Refutation, Paraphrasing	the editors to identify genre characteristics • Practice writing of counterclaim and refutation. • Peer and teacher conferences, use of checklists and rubrics, partial and full writing process use. Formative Assessment Sample • Write a counterclaim and refutation on an assigned issue/excerpt. Summative Assessment Sample • Write a letter to the editor on a current local issue or in response to a recent letter to the editor in your local paper. Be sure to include a counterclaim, refutation, and the 6 Traits.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Writing **GRADE: 8**

Language	L8.1,8.2, 8.3, 8.4, 8.5, 8.6	**Key Concept** Demonstrate understanding of punctuation, verb moods, and nuances in word meanings. **Essential Questions** • How do writers use active and passive voice effectively? • What is the difference between verb moods and how do writers use them effectively? • Which punctuation indicates different types of pauses within sentences? • What is the difference between connotation and denotation of words and how can denotations increase word choice efficacy? **Content Specific Language** Subjunctive, Conditional, Passive, Active, Connotation, Denotation	Formative Assessments • Lesson quiz on punctuation. • Use of new grammar lessons evidenced in writing. Formative Assessments • Write a paragraph in which you use new punctuation correctly in order to create different types of pauses • Lesson quiz on punctuation Summative Assessment Sample • Teach a lesson on an assigned grammar topic that includes lesson plans, direct instruction, classwork, homework, and an assessment.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Reading **GRADE: 8**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1. Fiction	RL. 8.1 RL. 8.2 RL. 8.3 RL. 8.4 RL. 8.5 RL. 8.6 RL. 8.7 RL. 8.9 RL. 8.10	**Short Stories and the Elements of Fiction ("Charles" By Shirley Jackson, "The Tell-Tale Heart," "Raymond's Run" "The Monkey's Paw" "The Necklace")** • How do we respond intelligently to literature using evidence from the text? • How do we use evidence to prove a claim (in literature)? • What are the elements of a character? • What is mood, and how can a reader? • What is the basic structure of a story, and how do writers manipulate the structure to create an effect? **Historic Fiction (*Forge* by Laurie Halse Anderson)** • What is Historic Fiction, and how is different from other genres and historic fact? • What does Historic Fiction teach us that history does not? • How does an author conduct research for a Historic Fiction novel? • How does Historic Fiction depict the time the story takes place and the time the story was written? • How does Historic Fiction differ from fiction that is historic? ***Sleeping Freshmen Never Lie* by David Lubar** • How does a Young Adult Genre book differ from Historic Fiction? • How does the author create and develop character? • How do dialogue, description, action, appearance, and thoughts and emotions help	Formative Assessment • CSETs • Reading Logs • Short Constructed Responses • Graphic Organizer • Class Discussion –Rubric • Unit Test • Creative Projects- Rubric Summative Sample Questions • In Shirley Jackson's "Charles" how does Jackson manipulate common plot structure to create an effect? • How does the myth of Prometheus relate to *Forge?* In what ways do the characters relate to the characters in the myth? • Give two examples of how Laurie Halse Anderson used epigraphs to introduce mood, theme, or idea within a chapter?

		in building a character? • How does the point of view of the novel generate conflict and humor? ***To Kill a Mockingbird* by Harper Lee** • How important is Point of View in this story? How can a change in point of view affect the themes, conflicts, and characterization of the novel? • How do authors build reoccurring symbols, and how do those symbols evolve? • How do reoccurring symbols help highlight a novel's theme? **Content Specific Vocabulary** Mood, theme, characterization, plot structure, conflict, exposition, climbing action, climax, falling action, resolution, dénouement, claim, set-up, evidence, tie in, primary source, genre, epigraph, theme, symbols, point of view	• Describe how Harper Lee's *To Kill A Mockingbird* paints a picture that the South as both a beautiful and ugly place?
Unit 2. Poetry & Drama	RL8.1 RL 8.2 RL 8.3 RL 8.4 RL.8.5 RL. 8.6 RL. 8.7 RL. 8.9 RL. 8.10	**Drama (*The Diary of Anne Frank*- Goodrich and Hackett, *Encore* Chamber Theatre Productions, *To Kill A Mockingbird* – Robert Mulligan)** • How does a dramatic piece differ from a novel? • How are methods of characterization different in a dramatic presentation versus fiction? • How faithful is a filmed or live production of a story? What choices did the director, actor, stage production crew, and costume designer make? What is the effect of their choices? **Poetry ("Intro to Poetry" Billy Collins, "A Noiseless Patient Spider" Walt Whitman, "The Red Wheelbarrow" William Carlos Williams, "Do Not Go Gentle Into That Goodnight" Dylan Thomas** • What kind of strategies does a poet use to point out theme?	Formative Assessment • CSETs • Short constructed responses • Graphic Organizers • Compare and Contrast • Projects- Rubric • Presentation- Rubric Summative Assessment • How did the Chamber Theatre's Production of "The Tell-Tale Heart" and "Monkey's Paw" present a similar mood

		• What kind of strategies does a poet use to generate mood? • How does the use of figurative language impact a poem's meaning? • How does punctuation, rhyme, stanza structure, syllable count, impact a poem as a whole **Content Specific Vocabulary** Director, state, scrim, stage left/right, script, screenplay, cinematographer, scene, close Up, establishing shot, voice over, props, acts, dialogue, stage directions, stanza, villanelle, annotation, figurative language, rhyme scheme, mood	on stage as found in the stories?
Unit 3 Non Fiction	RI.8.1 RI.8.2 RI.8.3 RI.8.4 RI.8.5 RI.8.6 RI.8.7 RI.8.8 RI.8.9 RI.8.10	**Upfront Magazine Articles** • How do authors effectively present their information, argument, or central idea? • How can a writer present their claim and give evidence? • What are the different types of persuasive devices used by writers? • How can we effectively use evidence to prove a claim? • How can we effectively use connect evidence to our claim in a tie-in? **Content Specific Vocabulary** Claim, setup, evidence, tie in, persuasive devices, bias, point of view, central idea, tone	Formative Assessment • Quiz • Reading Logs • CSETs • Graphic Organizer Summative Assessment • In a constructed response using evidence from the text explain why it can be argued that the United States and Philippines have a complicated relationship?
Unit 4 Proverbs	RL.8.1 RL.8.2 RL.8.4 RL.8.9 RI. 8.1	**Proverbs** • How can you figure the meaning of the proverb using context clues and an understanding of figurative language? • How can modern scenarios relate to these older sayings?	Formative Assessment • Homework • Class Presentation- Rubric • Quiz

	RI.8.2 RI.8.3 RI.8.4	• How can proverbs relate to my life? **Content Specific Vocabulary** Connotation, denotation, allusion, metaphor, definition, illustrate, relationship, personification, context, literal and figurative meaning	Summative Assessment- • Unit test • Which proverb matches the following scenario? When Rose and Julia decided to make up and be friends again, Julia still kept her anger inside and didn't really forgive Rose. Therefore, they could never be deep true friend until all the anger was gone.
Unit 5. Reading Logs	RL. 8.1 RL. 8.2 RL. 8.3 RL. 8.4 RL. 8.5 RL. 8.6 RL. 8.7 RL. 8.9 RL. 8.10 RI. 8.1 RI. 8.2 RI. 8.3 RI. 8.4 RI. 8.5 RI. 8.6 RI. 8.7 RI. 8.8	**Reading Logs** • How can we better understand an author's word choice and how it impacts the meaning of the text? • How do particular lines of dialogue reveal characterization? • How can we compare and contrast their text with previously read texts and make connections across texts? • How can we analyze the point of view the author uses to write the story? How would a story differ if told in a different perspective? **Content Specific Language** Objective summary, central idea, theme mood, tone, synthesize, point of view, characterization, plot structure	Formative Assessment • Weekly Reading Log • Graphic Organizer • CSET Summative Assessment • Binder Check Analyze the structure of a specific paragraph in your reading tonight. Discuss how that paragraph helps develop the central idea of the text.

	RI. 8.9 RI. 8.10		
Unit 6. Reviewing CSET	CCSS.ELA-Literacy. RL.8.1 RL.8.2 RL.8.5 RL.8.6 RI. 8.1 RI. 8.2 RI. 8.5 RI. 8.6	**Review of CSET** • What are the components of CSET? • How do we write a CSET? **Content Specific Language** Claim, set-up, evidence, tie-in, quote, supporting detail, inference, context, conclusion, transition, elaborate, details	Formative Assessments • Graphic organizers • Constructed responses • Text based writing Summative Assessment Sample Question • Using evidence from the text, discuss Curzon's character development in the Laurie Halse Anderson's novel *Forge.*

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors English **GRADE 9**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1-Elements of Fiction/Short Story Unit	**RL9-10.1 RL9-10.2 RL9-10.3 RL9-10.4 RL9-10.5 RL9-10.6 RL9-10.10 SL9.1 SL9-10.2 SL910-.3 SL9-10.4 SL9-10.5 L9-10.1 L9-10.2 L9-10.3 L9-10.4 L9-10.5 L9-10.6 W9-10.1 W9-10.2 W9-10.3 W9-10.4 W9-10.5 W9-10.6 W9-10.7 W9-10.8 W9-10.9 W9-10.10**	**Elements of Fiction/Short Stories** • What are the essential elements of fiction? • How does an author portray characterization? • In which ways does point of view affect the interpretation of events in a story? • How does dramatic irony affect the outcome of a story? **Texts** *Gift of the Magi* by Guy de Maupassant *The Most Dangerous Game* by Richard Connell *The Interlopers* by Saki *The Cask of Amontillado* by Edgar Allen Poe *The Scarlet Ibis* by James Hurst *Lamb to the Slaughter* by Roald Dahl *The Necklace* by Guy de Maupassant *Rules of the Game* by Amy Tan *The Girl Who Can* by Ama Ata Aidoo **Content Specific Vocabulary** Character development, setting, plot structure, theme, internal conflict, external conflict, mood, symbol, flashback, foreshadowing, point of view, third-person omniscient, third-person limited, first-person, dramatic irony.	Formative Daily journal warm ups/CSET Pre, during and post reading questions for oral and written response Teacher observation of whole class, individual, and collaborative work sessions Exit tickets Quizzes Summative End of Unit test Literary Analysis Paper End of marking period vocabulary test Performance Task Read and analyze a novel in preparation to give a book talk to the class. Prepare and present a book talk to class discussing the plot, setting, characters and theme of the chosen novel.
Unit 2-Non-fiction	**RL9-10.1 RL9-10.2 RL9.-10.10**	**Elements and Types of Non-fiction** • What are the essential elements of non-fiction?	Formative Daily journal warm ups/CSET

TEACHER'S NAME: Mindy Hete **6/17**

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CURRICULUM FRAMEWORK

COURSE: Honors English **GRADE 9**

	RI9-10.1 RI9-10.2 RI9-10.3 RI9-10.4 RI9-10.5 RI9-10.6 RI9-10.7 RI9-10.8 RI9-10.9 RI9-10.1 SL9.1 SL9-10.2 SL9-10.3 SL9-10.4 SL9-10.5 SL9-10.6 L9-10.1 L9-10.2 L9-10.3 L9-10.4 L9-10.5 L9-10.6 W9-10.1 W9-10.2 W9-10.3 W9-10.4 W9-10.5 W9-10.7 W9-10.8 W9- 10.9W 9-10.10	• How do authors organize factual information in essays, articles and speeches to present a picture of a topic? • How can an author's perspective change the way a reader views a topic? • What are the various rhetorical strategies writers use to get their meaning across? **Texts** "On Summer" by Lorraine Hansberry (reflective essay) "The News" by Neil Postman ((expository essay) "Libraries Face Sad Chapter" by Pete Hamill (persuasive essay) "I Have a Dream" by Martin Luther King Jr. "Ain't I a Woman?" by Sojourner Truth "The Gettysburg Address" by Abraham Lincoln Steve Job's Stanford Commencement Address **Content Specific Vocabulary** Essay (persuasive, reflective and expository), article (feature and news), speech, point of view, tone, diction, development of ideas, text structure, rhetoric, connotation, parallel structure, repetition, restatement, rhetorical question, ethos, pathos, and logos.	Reading response logs Exit tickets Socratic Seminar discussions Pre, during and post reading questions for oral discussions and written response Teacher observation of whole class, individual and collaborative work sessions Quizzes Summative End of unit test Text-based writing assessment End of marking period vocabulary test Performance Task Choose a topic to give a persuasive speech. Write, prepare and present a persuasive speech using rhetorical devices learned in this unit. Include ethos, pathos and logos in the speech.
Unit 3-Poetry	**RL9-10.1 RL9-10.2 RL9-10.3 RL9.10.4 RL9-10.5 RL9-10.7 RL9-10.10 SL9-10.1 SL9-10.2**	**Elements of Poetry** • What are the essential elements of poetry? • How do poets use rhythms and sounds to create patterns? • How do these patterns or repetitions affect your response to the poem? • How does figurative language help convey the meaning the poet intends?	Formative Daily journal warm ups/CSET Teacher observation of whole class, individual, and collaborative work sessions

	SL9.10.3 SL9-10.4 SL9.10.5 SL9-10.6 L9-10.1 L9-10.2 L9-10.3 L9.10.4 L9-10.5 L9-10.6 W9-10.1 W9-10.2 W9-10.3 W9-10.4 W9-10.5 W9-10.6 W9-10.7 W9-10.8 W9-10.9 W9-10.10	**Texts** *Pearson Common Core Literature Grade 9* text-Unit 3 **Content Specific Vocabulary** Alliteration, allusion, connotation, denotation, assonance, imagery, free verse, formal verse, meter, rhythm, rhyme scheme, end, slant, and internal rhyme, stanza, couplet, personification, simile, metaphor, symbolism, theme, diction, mood, tone, ballad, ode, sonnet, and haiku.	Whole class discussions Study questions Exit tickets Quizzes Summative End of unit test Text-based writing assessment End of marking period vocabulary test Performance Task Choose a poem and give a three minute oral commentary using the IB oral commentary as a guide.
Unit 4-*The Odyssey*/ Hero's Journey-Joseph Cambell's Monomyth	**RL9-10.1 RL9-10.2 RL9-10.3 RL9-10.4 RL9-10.5 RL9-10.6 RL9.7 RL9-10.9 RL9-10.10 SL9-10.1SL9-10.3 SL9-10.4 SL9-10.5**	**Elements of The Hero's Journey** • What are the steps in the hero's journey? • What is an epic hero? • What is an epic poem? • How is *The Odyssey* an example of the hero's journey and an epic poem? • What do all epic heroes have in common? **Texts**	Formative Daily journal warm ups/CSET Teacher observation of whole class, individual, and collaborative work sessions Whole class discussions Pre, during, and post reading questions

	SL9-10.6 L9-10.1 L9-10.2 L9-10.3L9-10.4 L9-10.5 L9-10.6 **W9-10.2 W9-10.3 W9-10.4 W9-10.5 W9-10.9 W9-10.10**	*The Odyssey* in *Pearson Common Core Literature Grade 9* text-Unit 5 **Content Specific Vocabulary** Epic hero, epic poem, the hero's journey/monomyth (Joseph Campbell), epic simile, archetype, point of view, theme, epithet, in medias res, lofty style, epic flaw, and heroic qualities.	for oral and written response Exit tickets Quizzes Summative End of unit test Oral presentation (partner project tracing the hero's journey steps in a modern movie) Performance Task *Trojan Times* Newspaper project Create a two-page newspaper spread complete with articles and pictures. Articles should reflect events in *The Odyssey*.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors English **GRADE 9**

Unit 5-Drama	**RL9-10.1 RL9-10.2 RL9-10.3 RL9-10.4 RL9-10.5 RL9-10.6 RL9-10.9 RL9.10.10 SL9-10.4 SL9-10.5SL9-10.6L9-10.1 L9-10.2L9-10.3 L9-10.4 L9-10.5 L9-10.6 W9-10.1 W9-10.2 W9-10.3 W9-10.4 W9-10.5 W9-10.6 W9-10.7 W9-10.8 W9-10.9 W9-10.10**	**Elements of Drama** • How does a dramatic piece differ from a novel? • How does the affectation of lines being read in a play add to the emotions of the characters and the audiences understanding? • How can the use of dialogue make a literary work more or less effective? **Texts** *Romeo and Juliet-Pearson Common Core Literature Grade 9-Unit 4* Excerpt from *A Midsummer's Night Dream-Common Core Literature Grade 9-Unit 4* **Content Specific Vocabulary** Act, scene, stage directions, Globe Theatre, theme, tragedy, comedy, irony, tragic hero, tragic flaw, monologue, soliloquy, aside, foil, character types-flat, round, static, dynamic, and characterization in drama.	Formative Daily journal warm ups/CSET Teacher observation of whole class, individual and collaborative work sessions Whole class discussions Study questions Exit tickets Quizzes Summative End of Unit test End of marking period vocabulary test Tex-based writing assessment Performance Task Timed writing-Write an essay explaining why Shakespeare might explore the story of ill-fated love in both a comedy and a tragedy such as *Romeo and Juliet* and *A Midsummer Night's Dream.*

TEACHER'S NAME: Mindy Hete **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors English **GRADE 9**

TEACHER'S NAME: Mindy Hete **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Elements of Writing **GRADE: 9**

Unit	Standards	Unit Concept /Essential Questions	Assessments
Research and Writing	CCSS.ELA-Literacy.WHST.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. CCSS.ELA- Literacy.WHST.9-10.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. CCSS.ELA- Literacy.WHST.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. CCSS.ELA- Literacy.WHST.9-10.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.	**Research Paper Pre-Test (Student Selected Topic)** • What do I already know about the research process? • What is my current research and writing ability?	SUMMATIVE: Source Comparison Chart Final Draft (Rubric Scored)
CSET	CCSS.ELA-Literacy.WHST.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	**Most Important Rule Writing Assignment** • What do I already know about writing a CSET paragraph? • How can I successfully write a CSET paragraph?	SUMMATIVE: Note taking Teacher observation of whole class Think pair share discussions Class modeling Class discussions Exit ticket

TEACHER'S NAME: Jen Leonard **6/17**

COURSE: Elements of Writing **GRADE: 9**

			FORMATIVE: CSET Rubric
Formatting	CCSS.ELA-Literacy.L.9-10.3 Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening. CCSS.ELA-Literacy.L.9-10.3.a Write and edit work so that it conforms to the guidelines in a style manual (e.g., *MLA Handbook*) appropriate for the discipline and writing type.	**MLA Formatting** **-Header** **-Heading** **-Title** **-Double Spacing** **-In Text Citations** **-Works Cited Page** • Why is it important to use correct MLA Formatting?	SUMMATIVE: Note taking Teacher observation of whole class Think pair share discussions Class discussions Revision exercises Analysis of examples Entrance Tickets FORMATIVE: MLA Quiz
Research and Writing	CCSS.ELA-Literacy.WHST.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. CCSS.ELA- Literacy.WHST.9-10.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. CCSS.ELA- Literacy.WHST.9-10.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically. CCSS.ELA- Literacy.WHST.9-10.7	**Essay-Teen Sleep Needs** **-Synthesizing** **-Source Comparison** • How do I synthesize information from informational texts? • How do I use the Sussex Academy library to locate reliable sources? • How do I use the Delaware library database to locate reliable sources? • How do I use UDLibSearch to locate reliable sources? • How do I use PowerSearch to locate reliable	FORMATIVE: Teacher observation of whole class Individual and collaborative work sessions Class discussions Individual student/teacher conferences Writing Multiple Drafts Revision exercises Analysis of examples

	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. CCSS.ELA-Literacy.WHST.9-10.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. CCSS.ELA-Literacy.WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research. CCSS.ELA- Literacy.WHST.9-10.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.	sources? • How do I evaluate a source for reliability? • How is the editing and revising stage of the writing process crucial to the final draft of a research paper?	SUMMATIVE: Final Draft (Rubric Scored)
Research and Writing	CCSS.ELA-Literacy.WHST.9-10.1 Write arguments focused on *discipline-specific content.* CCSS.ELA-Literacy.WHST.9-10.1.a Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence. CCSS.ELA-Literacy.WHST.9-10.1.b	**Essay-Which makes individuals happier: Possessions or Experiences?** **-Source Cards** **-Note Cards** • What is the structure of source cards and note cards and why is this structure important? • How can creating source cards and note cards help me organize my gathered information for the writing of a research paper?	FORMATIVE: Teacher observation of whole class Individual and collaborative work sessions Class discussions Individual student/teacher conferences Writing Multiple Drafts

	Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns. CCSS.ELA-Literacy.WHST.9-10.1.c Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. CCSS.ELA-Literacy.WHST.9-10.1.d Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. CCSS.ELA-Literacy.WHST.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. CCSS.ELA- Literacy.WHST.9-10.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. CCSS.ELA- Literacy.WHST.9-10.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically. CCSS.ELA- Literacy.WHST.9-10.7 Conduct short as well as more sustained research projects to answer a		Revision exercises Analysis of examples SUMMATIVE: Final Draft (Rubric Scored)

	question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. CCSS.ELA- Literacy.WHST.9-10.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.		
Writing a Letter	CCSS.ELA-Literacy.WHST.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. CCSS.ELA- Literacy.WHST.9-10.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. CCSS.ELA- Literacy.WHST.9-10.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically. CCSS.ELA- Literacy.WHST.9-10.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.	**Letter to the Editor** • What is the appropriate format for writing a letter to the editor? • Why is tone important when producing a letter?	FORMATIVE: Teacher observation of whole class Individual and collaborative work sessions Class discussions Individual student/teacher conferences Writing Multiple Drafts Revision exercises Analysis of examples SUMMATIVE: Final draft (Rubric Scored)
Language	CCSS.ELA-Literacy.L.9-10.1 Demonstrate command of the conventions of standard English	**Grammar** **-Run-on Sentences & Fragments**	FORMATIVE: Worksheets

	grammar and usage when writing or speaking. CCSS.ELA-Literacy.L.9-10.1.a Use parallel structure.* CCSS.ELA-Literacy.L.9-10.1.b Use various types of phrases (noun, verb, adjectival, adverbial, participial, prepositional, absolute) and clauses (independent, dependent; noun, relative, adverbial) to convey specific meanings and add variety and interest to writing or presentations. CCSS.ELA-Literacy.L.9-10.2 Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing. CCSS.ELA-Literacy.L9-10.2.A Use a semicolon (and perhaps a conjunctive adverb) to link two or more closely related independent clauses. CCSS.ELA-Literacy.L9.10.2B Use a colon to introduce a list or quotation. CCSS.ELA-Literacy.L9-10.2.C Spell correctly. CCSS.ELA-Literacy.L9-10.6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.	**-Subject-Verb Agreement** **-Pronoun Antecedent Agreement** **-Parallel Structure** **-Misplaced Modifiers** **-Semicolon/colon** How can understanding grammar and sentence structure better assist me while writing?	Grammar Bytes on chompchomp.com (Students complete the independent practice on handouts and then check their answers using the interactive tool online.) SUMMATIVE: Run-on sentences and fragments quiz Subject-Verb agreement quiz Pronoun antecedent agreement quiz Parallel structure quiz Misplaced modifier quiz Semicolon/colon quiz
Research and Writing	CCSS.ELA-Literacy.WHST.9-10.4 Produce clear and coherent writing in which the development,	**Research Paper Post-Test (Student Selected Topic)**	SUMMATIVE: Source Comparison Chart

	organization, and style are appropriate to task, purpose, and audience. CCSS.ELA- Literacy.WHST.9-10.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. CCSS.ELA- Literacy.WHST.9-10.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically. CCSS.ELA- Literacy.WHST.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. CCSS.ELA-Literacy.WHST.9-10.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. CCSS.ELA-Literacy.WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research. CCSS.ELA- Literacy.WHST.9-10.10 Write routinely over extended time frames (time for research, reflection,	• What do I know about the research process? • What is my current research and writing ability?	Final Draft (Rubric Scored)

	and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.		
Speaking and Listening	CCSS.ELA-Literacy.SL.9-10.1 Initiate and participate effectively in a range of collaborative discussions (in groups) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively. CCSS.ELA-Literacy.SL.9-10.4 Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task. CCSS.ELA-Literacy.SL.9-10.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. CCSS.ELA-Literacy.SL.9-10.6 Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.	**Research and Writing Presentation** • What have I learned about the research and writing process?	FORMATIVE: Written Peer Feedback Presentation (Rubric Scored)

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Health **GRADE: 9**

Unit	Standards	Unit Concept /Essential Questions	Assessments
Physical Health	**DE Health Standards** 1.1 1.4 1.5 1.7 1.8 2.1 2.8 3.4 5.3 5.5 5.6 6.1 7.2 8.2 8.4 **Focus:** Digestive System Nutrition Cardiovascular System Nervous System Skeletal System	**Unit 1 – Physical Health -Essential Questions** • What is health? • How do food choices help to support a healthy life style? • How do your choices relate to the functioning of your body systems? • How do the structure and functions of our body systems allow us to meet our physical needs? • How does the use of alcohol and drugs affect our body systems? **Content Specific Vocabulary** epiglottis, stomach, small intestine, colon, digestion, peristalsis, bile, gallbladder, nutrient, metabolism, calorie, carbohydrate, fiber, fat, unsaturated fat, saturated fat, cholesterol, trans fat, protein, amino acid, joint, cartilage, ossification ,marrow, ligament, osteoporosis, fracture, sprain, dislocation, scoliosis, smooth muscle, cardiac muscle, skeletal muscle, neuron, cerebrum, cerebellum, brain stem, spinal cord, atrium, ventricle, artery, capillary, vein, blood pressure, plasma, red blood cell, white blood cell, platelet, atherosclerosis, arrhythmia, pituitary gland, puberty, sperm, fertilization, testes, testosterone, scrotum, penis, semen, infertility, ova, ovaries, estrogen, progesterone, ovulation, fallopian tubes, uterus, vagina, sexually transmitted infection, depressant, intoxication, blood alcohol concentration (BAC), overdose, binge drinking, barbiturates, opiate, amphetamines **Text** Pruitt, B E., John P. Allegrante, and Deborah Prothrow-Stith. *Health*. Boston, Pearson, 2014. Journal articles as related to the topic	Lesson Quizzes - Formative Unit Test - Summative Digestive System Story – Summative Students write a first person narrative from the perspective of a chocolate chip cookie on its passage through the digestive system. Correct anatomical descriptions are required. Meal Planning – Formative Students record their daily food intake and then assess how they met basic nutrition needs based on their diet. Recommendations for changes to eating habits in order to maintain a healthier life style are required. Digestive System Model – Formative Students work together to create a human model of the digestive system. STD Brochure – Formative Students design a brochure to be handed out to fellow students discussing important information regarding a specific

TEACHER'S NAME: Stephanie Sherman **6/17**

	Reproductive System Sexually Transmitted Diseases Alcohol and Drug Use		sexually transmitted disease. Heart Rate Lab – Formative Students perform a lab in which they monitor their heart rate and determine what effect exercise has on heart rate. PSA Drug and Alcohol Use Video – Formative Students write, direct, and perform a public service announcement that warns teens of the affects of alcohol and drugs on the body.
Emotional and Mental Health	**DE Health Standards** 1.1 1.3 1.4 1.5 2.1 2.3 2.4 2.5 2.7 3.1 3.4 5.1 5.3	**Unit 2: Mental and Emotional Health - Essential Questions** • What influences my mental and emotional health? • What does it mean to be mentally and emotionally healthy? • How does stress influence health? • How do mental health disorders affect students and communities? **Content Specific Vocabulary** heredity, risk factor, prevention, personality, peer group, identity, self-esteem, self-actualization, hierarchy of needs, primary emotion, learned emotion, coping strategy, defense mechanism, stress, eustress, distress, stressor, optimism, pessimism, perfectionist, resilience, mental disorder, anxiety, anxiety disorder, phobia, obsession, compulsion, mood disorder, depression, schizophrenia, personality disorder, eating disorder, anorexia nervosa, bulimia, binge eating disorder, clinical depression, cutting, suicide, cluster suicide	Lesson Quizzes – Formative Unit Test – Summative Stress Infographic – Summative Students create an infographic to represent information learned about both good and bad stress, its effects on the body, and ways to positively manage stress. Personality Development Timeline – Formative Students create a timeline of personality development, which includes major

	5.5 6.3 7.1 7.3 8.2 8.4 Focus: Self-esteem Stress management Personal health Mental illness Suicide prevention	**Text** Pruitt, B E., John P. Allegrante, and Deborah Prothrow-Stith. *Health*. Boston, Pearson, 2014. Journal articles as related to the topics	milestones within each stage. The status of self-esteem during each stage will also be indicated. Self Esteem Role Play – Formative Students role-play hypothetical situations that occurs in the lives of teenagers and reflect on the effect of these situations on the self-esteem of all involved. Stressed and Depressed Letter – Summative Students will write a letter to a "stressed and depressed" student addressing his/her depression and what might help them feel better and also outlines coping strategies that can be employed. Stigma Elimination Presentation – Formative Students research a form of mental illness and then present the myths and truths to their classmates with the goal of educating and eliminating the stigma that surrounds mental illness.
Social Health	**DE Health Standards** 1.2	**Unit 3: Social Health – Essential Questions** • What barriers exist to hinder healthy decision making? • How do the influences of peer groups, family, and culture affect decision making?	Unit Test – Summative Lesson Quizzes - Formative

	1.7 2.1 2.2 2.3 2.5 4.1 4.2 4.3 4.4 5.2 5.5 5.6 8.1 8.2 **Focus:** Assertive Communication Conflict Resolution Peer Pressure	• How does effective communication influence health? **Content Specific Vocabulary** Empathy, communication, active listening, passive, aggressive, assertive, body language, eye contact, cooperation, compromise, infatuation, dating violence, date rape **Text:** Pruitt, B E., John P. Allegrante, and Deborah Prothrow-Stith. *Health.* Boston, Pearson, 2014. Journal articles as related to the topics	Peer Pressure Performance – Formative Students are given scenarios where they need to identify the role of peer pressure and then w role-play effective assertive communication to deal with the peer pressure. Active Listening/Conflict Resolution – Performance Task Students will be asked to participate in a role- play where conflict arises and they will need to use active listening and conflict resolution skills that they have learned in class to come to a resolution.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Ellis & Associates Lifeguarding **GRADE: 10-12**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Prerequisites		**Key Concept** • Am I able to swim 200 yards without stopping? • Can I tread water for 2 minutes? • Can I retrieve a 10-pound brick from the bottom of the pool? **Content Specific Vocabulary** Breaststroke, crawl, feet-first surface dive	Teacher observation: 200 yard swim, 2-minute tread, 10-pound brick retrieval from bottom of pool - Summative
Unit 1 **The Professional Lifeguard/The Vigilant Lifeguard**		**Learning Outcomes** **Professional Lifeguard** • Define "standard of care" and how it relates to the job of a lifeguard • Describe how a professional lifeguard looks and acts • Describe how a professional lifeguard maintains personal safety • Describe to whom a professional lifeguard is held accountable and why • Explain how an aquatic facility may audit a professional lifeguard's performance **Vigilant Lifeguard** • Define the concept of vigilance and describe how it applies to lifeguarding • Describe and perform the 10/20 Protection Standard • Describe how Zone of Protection areas assist lifeguards in maintaining vigilance • Perform methods of proactive scanning • Describe how to recognize a guest in distress • Describe the drowning process • Describe high-risk guests, locations, and times • Describe distractions and how to avoid them **Content Specific Vocabulary** Standard of care, 10/20 Protection Standard, professional image, hip pack, whistle, rescue tube,	Check Your Understanding Quiz – Formative Teacher observation: scanning, how to hold a rescue tube, use of PPE - Summative

		standard precautions, personal protective equipment (PPE), test-ready level, accountability, vigilance, Zone of Protection, scanning, guest in distress (GiD)	
Unit 2 **Lifeguard Team & Emergency Action Plans/Guest Relations & Other Responsibilities**		**Learning Outcomes** **The Lifeguard Team & Emergency Action Plans** • Demonstrate how lifeguards communicate with other staff, guests, and EMS • Describe the components of an emergency action plan (EAP) • Explain why EAPs are critical for lifeguard teams • Demonstrate how lifeguards rotate at duty stations • Define a rescue and an assist • Describe events that occur during and after a rescue taking place **Guest Relations & Other Responsibilities** • Describe how to effectively enforce pool rules and policies • Demonstrate how to select, fit, and properly maintain life jackets • Describe potential weather-related incidents and response • Describe different types of documentation you may be asked to complete **Content Specific Vocabulary** Communication system, whistle codes, hand signals, emergency action plan (EAP), rescue, assist, lifeguard rotation, elevated station, deck level station, proactive bottom scan, CARE philosophy, DEAL philosophy, golden rule of guest relations, in-service training	Check Your Understanding Quiz – Formative Teacher observation: lifeguard rotation, assists, communication system – Summative
Unit 3 **Respiratory Emergencies/ Supplemental Oxygen Support**		**Learning Outcomes** **Respiratory Emergencies** • Describe how to assess a motionless guest • Demonstrate how to provide rescue breathing with a resuscitation mask for an unresponsive, non-breathing guest • Demonstrate how to care for an airway obstruction in a responsive or unresponsive guest • Demonstrate how to use a manual suction device	Check Your Understanding Quiz – Formative Teacher observation: assess the scene, rescue breathing, airway obstruction on conscious and unconscious guest, use of SOS system – Summative

		Supplemental Oxygen Support • Describe the benefits of using supplemental oxygen during resuscitation of a drowning guest • Explain the parts of a supplemental oxygen support (SOS) system • Demonstrate how to use an SOS system • Explain safety precautions when using an SOS system • Explain basic care and maintenance of an SOS system • Demonstrate how to use a bag-valve-mask attached to an SOS system **Content Specific Vocabulary** Agonal breaths, airway obstruction, choking, Heimlich maneuver, jaw thrust, manual (handheld) suction device, recovery position, rescue breathing, responsive, resuscitation mask, unresponsive, bag-valve-mask (BVM), non-rebreathing mask, pressure regulator, pulse oximeter, pulse oximetry, supplemental oxygen support (SOS) system	
Unit 4 **Cardiac Emergencies**		**Learning Outcomes** **Cardiac Emergencies** • Describe how the heart functions • Describe how to provide care for a guest experiencing cardiac arrect • Demonstrate how to provide cardiopulmonary resuscitation (CPR) for an adult, child, and infant in cardiac arrest • Describe the purpose of defibrillation • Demonstrate how to use an automated external defibrillator (AED) • Describe how to handle special considerations associated with the use of an AED **Content Specific Vocabulary** Automated external defibrillator (AED), defibrillation, cardiac arrest, cardiopulmonary resuscitation	Check Your Understanding Quiz – Formative Teacher observation: CPR on adult, infant, and child, use of an AED – Summative

		(CPR), ventricular fibrillation, ventricular tachycardia	
Unit 5 **First Aid**		**Learning Outcomes** **Injuries** • Recognize types of injuries that commonly occur in aquatic facilities • Describe how to assess an injured guest • Describe how to care for injuries to the head, spine, chest, abdomen, pelvis, and extremities • Recognize and care for shock resulting from injury • Demonstrate how to provide care for a guest who has external bleeding • Demonstrate how to provide care for a guest with a muscle, bone, or joint injury **Medical and Environmental Emergencies** • Recognize the type of medical and environmental emergencies that commonly occur in aquatic facilities • Describe how to care for medical emergencies that include asthma, heart attack, stroke, seizure, fainting, allergic reactions, poisoning, and diabetic emergencies • Describe how to care for environmental emergencies that include heart and cold illnesses, and bites and stings **Content Specific Vocabulary** Bruise, dislocation, DOTS, fracture, inline stabilization, RICE, secondary assessment, shock, sign, splinting, sprain, strain, symptom, anaphylaxis, asthma, epinephrine auto-injector, EpiPen, fainting, heart attack, hyperglycemia, hypoglycemia, hypothermia, seizure, stroke	Check Your Understanding Quiz – Formative Teacher observation: how to care for different injuries that may occur in aquatic facility – Summative
Unit 6 **Active Guest in Distress**		**Learning Outcomes** **Active Guest In Distress Rescues** • Perform the arm extension and rescue tube assists • Perform the compact jump and approach stroke	Check Your Understanding Quiz – Formative Teacher observation: recognizing and responding to active guest in distress

Rescues		• Perform the front drive rescue • Perform adjustments to the front drive rescue • Perform the rear hug rescue • Perform the duck pluck rescue • Perform the deep-water rescue • Describe how you would handle a rescue involving multiple guests in distress **Content Specific Vocabulary** Approach stroke, compact jump entry, front drive rescue, front hug position, deep-water rescue, push-away technique, extension assist, rear hug rescue, flip-over technique, two-lifeguard rescue	with appropriate rescue – Summative
Unit 7 **Unresponsive Guest in Distress Rescues**		**Learning Outcomes** **Unresponsive Guest in Distress Rescues** • Demonstrate how to perform the unresponsive rear hug rescue • Demonstrate how to perform the unresponsive duck pluck rescue • Demonstrate how to perform the unresponsive deep-water rescue • Demonstrate how to open the airway of an unresponsive guest in the water • Demonstrate how to perform the rapid extrication of an unresponsive guest from the water **Content Specific Vocabulary** Unresponsive deep-water rescue, unresponsive duck pluck rescue, unresponsive rear hug rescue, rapid extrication	Check Your Understanding Quiz – Formative Teacher observation: recognizing and responding to unresponsive guest in distress with appropriate rescue – Summative
Unit 8 **Spinal Injury Management**		**Learning Outcomes** **Spinal Injury Management** • Identify situations that could result in a spinal injury in aquatic facilities • Identify the signs and symptoms of a spinal injury • Demonstrate how to provide care for a guest who has a possible spinal injury in the water • Demonstrate how to provide care for a guest who has a possible spinal injury on land	Check Your Understanding Quiz – Formative Teacher observation: recognize and respond appropriately to a spinal injury

		Content Specific Vocabulary Backboarding, distracting injury, manual spinal motion restriction, mechanism of injury, overarm vise grip, underarm vise grip, rapid extrication technique, spinal motional restriction, squeeze play technique	in the water and on land – Summative
Unit 9 **Final Exam and Test-out**		**Demonstrate competency in the following skills:** • Conscious guest on surface rescues • Conscious guest below the surface rescues • Conscious guest on the bottom rescues • Unconscious guest on the surface rescues • Unconscious guest below the surface rescues • Unconscious guest on the bottom rescues • Suspected spinal and extrication (2 person and team scenarios) • Health Care Provider Basic Life Support, including CPR, AED, Oxygen Administration, and First Aid (individual and team scenarios)	Written Final Exam – Summative Test-Out Scenarios – Summative

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Personal Finance **GRADE: 10**

Unit	Standards	Unit Concept /Essential Questions	Assessments
1- Financial Planning and Decision-Making	PF1	**Essential Questions:** • How do individual goals affect the value of benefits and costs of alternative choices? • How might making choices today affect life in the future? • How might one use the economic way of thinking to make informed decisions? **Content Specific Vocabulary** Wealth building, economic reasoning, decision-making, scarcity	Formative: (Simulations/Activities) How To Really Be a Millionaire The Economic Way of Thinking Making a Job Invest in Yourself Summative: (Project Presentation) Dreams and Plans
2- Money Management	PF2	**Essential Questions:** • How might budgeting contribute to financial success? • Why might financial planning be important in order to reach goals? • How does paying taxes affect income? • What effect does compound interest have on net wealth? **Content Specific Vocabulary** Human capital, income, opportunity cost, budgeting, spending, gross pay, net pay, taxes, fixed expenses, variable expenses, compound interest, rate of return	Formative: (Simulations/Activities) Funding My Goals by Planning Uncle Sam Takes a Bite Summative: (Project Presentation) Obtaining Financing: Shop for Your Mortgage
3- Saving and Investing	PF3	**Essential Questions:** • How can saving money help achieve financial goals? • What is the relationship between risk and reward when investing? • How might one decide what type of investment will best fit needs? • What role can financial institutions play in saving and investing? • How might a fundamental analysis of a company's performance help make an investment decision? **Content Specific Vocabulary** Savings goal, compound interest diversification, risk, reward, money market mutual funds, certificate of deposit, U.S. government savings bonds, limited liability, price/earnings ratio, fundamental analysis	Formative: (Simulations/Activities) There Is No Free Lunch in Investing Financial Institutions in the U.S. Economy How to Buy and Sell Stocks and Bonds Summative: (Project Presentation) Portfolio Builder Stock Simulation
4- Risk Protection	PF4	**Essential Questions:**	Formative: (Simulations/Activities)

		• How do consumer protection laws protect people? **Content Specific Vocabulary** Credit protection, redress of credit problems	Cash or Credit: Which to Use When Finding Your Way Through the Credit Maze Shopping for a Credit Card Why Insurance and How Does It Work? Summative: (Project Presentation) Let the Buyer Beware

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Swim Conditioning **GRADE: HS**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1 **Intro to Swim Conditioning**		**Swim Conditioning** • What does conditioning mean? • How far can I swim? • How fast can I swim • How can I improve? **Content Specific Vocabulary** Drill, kick, pull, pull buoy, kickboard, hand paddles, fins, pace clock, sets, sprint, distance, freestyle, backstroke, breaststroke, streamline, flip turn, open turn, pace, lane line, lane leader, dive, starting block	Distance swim test: used in pre-test and post-test format – Formative Pace swim test: used in pre-test and post-test format – Formative
Unit 2 **Freestyle**		**Freestyle Stroke** • What are the main characteristics of freestyle? • What muscle groups are targeted by freestyle? • What kind of kick do I use for freestyle? • What kind of drills can I use for freestyle? • Can I perform a flip turn for freestyle? • Can I swim multiple lengths of the pool using freestyle stroke? **Content Specific Vocabulary** Freestyle, front crawl, hyper streamline, catch, finger-drag, catch-up, 6-beat kick, 2-beat kick, flutter kick, rhythmic breathing, flip turn	Homework: design a freestyle specific workout using drills – Summative Swim a 200 yard freestyle - Formative
Unit 3		**Backstroke** • What are similar/different qualities between backstroke and freestyle? • What muscle groups are targeted by backstroke?	Homework: design a backstroke specific workout using drills –

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Swim Conditioning **GRADE: HS**

Backstroke		• What kind of kick do I use for backstroke? • What kind of drills can I use for backstroke? • Can I perform a flip turn for backstroke? • Can I swim multiple lengths of the pool using backstroke? **Content Specific Vocabulary** Backstroke, nose clip, single-arm backstroke, butterfly kick, bent elbow pull, 'Three R's' (relaxation, rotation, rhythm), flip turn	Summative Swim a 200 yard backstroke - Formative
Unit 4 **Breaststroke**		**Breaststroke** • What are the characteristics of breaststroke? • What muscle groups are targeted by breaststroke? • What kind of kick is used for breaststroke? • What kind of drills can I use for breaststroke? • Can I perform a breaststroke pullout? • Can I perform an open turn for breaststroke? • Can I swim multiple lengths of the pool using breaststroke? **Content Specific Vocabulary** Breaststroke, insweep, recovery, breaststroke kick, stroke timing, scull, elementary backstroke, breaststroke pullout, open turn	Homework: design a breaststroke specific workout using drills – Summative Swim a 100 yard breaststroke - Formative
Unit 5 **Butterfly**		**Butterfly** • How did butterfly originate? • What are the characteristics of butterfly? • What muscle groups are targeted by butterfly? • What kind of kick is used for butterfly? • What kind of drills can I use for butterfly? • Can I perform an open turn for butterfly? • Can I swim multiple lengths of the pool using butterfly?	Homework: design a butterfly specific workout using drills – Summative Swim a 100 yard butterfly - Formative

		Content Specific Vocabulary Butterfly, undulation, vertical kick, power phase, one-arm butterfly, dolphin kick, head position, open turn	
Unit 6 **Individual Medley/Intro to Competitive Swimming**		**Individual Medley** • What is an individual medley? • What is the order of the strokes in an individual medley? • Can I perform the legal open turns for an individual medley? • Can I swim an individual medley? **Content Specific Vocabulary** Individual medley (I.M.), open turn, bucket turn **Competitive Swimming** • What are the names of major competitions in swimming? • What is the difference between yard and meter? • What is the difference between short course and long course? • What are the events in a typical swim competition? • What is a relay? • Can I swim on a relay as part of a team? • Can I perform a start from the block? • Can I perform an in-water start from the backstroke bars? **Content Specific Vocabulary** Swim meet, yard, meter, short course, long course, relay, medley relay, event, track start, backstroke bars, backstroke start, relay exchange	Swim a 100 yard individual medley – Formative Homework: design a workout encompassing all 4 competitive strokes – Summative Compete in a mock swim meet – Summative

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: US History **GRADE: 11**

Unit	Standards	Unit Concept/Essential Questions	Assessments
The Colonies	H1 6-8a 9-12a H2 6-8a 6-8b 9-12a 9-12b H3 9-12a H4 9-12b	**Concept 1 Northern, Middle, and Southern colonies** **Essential Questions:** • How has geography influenced the development of the colonies? • How did the colonies differ in origin and structure? **Concept 2 Roots** **Essential Questions:** • How did the colonial period help to shape America's ideals? • What were some of the early problems that led to ideas about government? **Concept 3 French and Indian War** **Essential Questions:** • What were the events that led to the French and Indian War? **Content Specific Vocabulary** Mayflower Compact, indentured servants, confederation, Great Awakening	Formative Indentured servitude document study and DBQ Jamestown Artifacts Activity Text reading and questions Summative Join or Die reading- French and Indian Foundations of Government DBQ Quiz 1 Formative Sample Question What were the events that led to the French and Indian War? Summative Sample Question What were the different ideas about how our country should govern itself? Summative Performance Task Create a graphic organizer illustrating social, political, and economical differences in Northern, Middle, and Southern colonies
Revolution	H1 6-8a 9-12a H2 6-8a 6-8b 9-12a 9-12b	**Concept 1 Road to Revolution** **Essential Questions:** • What were the major events that led to the American Revolution and • what were the outcomes of those events and the war? • Were the American colonists justified in rebelling against British rule? • Who were the key players in bringing the colonies to rebellion?	Formative Point of view –The Boston Massacre Gilder Lehman- Common Sense reading and activity Chapter readings and questions Summative Guided DBQ- Causes of the Revolution

TEACHER'S NAME: Desmond **6/17**

	H3 9-12a H4 9-12b	**Concept 2 Fighting the War** **Essential Questions:** • What were the major political and military strategies that brought success to the colonists? **Content Specific Vocabulary** Stamp Act, boycott, committees of correspondence, Intolerable Acts, militias, mercenaries, guerilla warfare	Primary Sources Activity- Homefront Quiz Formative Sample Question What were the major events that led to the Revolution? Summative Sample Question Describe the outcomes of the events and the war? Summative Performance Task Participate in the trial of British officers after the Boston Massacre.
The New Nation	H1 6-8a 9-12a H2 6-8a 6-8b 9-12a 9-12b H3 9-12a H4 9-12b	**Concept 1 Articles of Confederation and US Constitution** **Essential Questions:** • How does federalism shape society? • How did the weaknesses of the Articles lead to a new government? • What were the arguments of the Federalists and anti-Federalists? **Concept 2 The Federalist Period** **Essential Questions:** • What was the impact of the major domestic issues and conflicts experienced by nations in the Federalist Era? • How did the Federalist Period contribute to long standing debate in America about the role of government and the distribution of power? **Content Specific Vocabulary** Constitutional Convention, ratification, ordinance, tariffs, delegates, checks and balances	Formative Road to the Constitution Simulation Ted Ed video on democracy George Washington Farewell Address & Jefferson's First Inaugural Address- Analysis of leadership differences Summative Compare/Contrast- Declaration and Constitution Town Hall Debate- Federalist vs Anti-Federalists Formative Sample Question What were the weaknesses in the Articles of Confederation? Summative Sample Question How did the failures of the Articles shape the Constitution?

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: US History **GRADE: 11**

			Summative Performance Task Develop a song or skit highlighting the arguments of the Federalists.
Expansion and Reform	H1 6-8a 9-12a H2 6-8a 6-8b 9-12a 9-12b H3 9-12a H4 9-12b	**Concept 1 Expansion** **Essential Questions:** • What tactics can citizens use to influence government? • How can expansion lead to conflict and change? • What effect did territorial expansion have on the development of a new nation? **Concept 2 Sectionalism and nationalism** **Essential Questions:** • How were nationalism and sectionalism reflected in economic and social issues of the era? • How do economic and social conditions effect innovation and change? **Concept 3 Reform Movements** • What characteristics define a perfect society? • To what extent was the debate over slavery essential to the reform movements? **Content Specific Vocabulary** Manifest Destiny, suffrage, cotton gin, Second Great Awakening, abolition	Formative Roleplay of freedoms available to different groups Summit on alternative policies Territorial expansion jigsaw puzzle project Graphing activity –locations of various industrial, agricultural, and technological activities Chapter readings and questions Summative Newspaper editorial opposing discriminating practices Test Formative Sample Question What were the major reforms of this period? Summative Sample Question How were nationalism and sectionalism reflected in social and economic issues of the era? Summative Performance Task

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CURRICULUM FRAMEWORK

COURSE: US History **GRADE: 11**

			Contribute a letter to the editor newspaper urging Congress to encourage expansion
Civil War and Reconstruction	H1 6-8a 9-12a H2 6-8a 6-8b 9-12a 9-12b H3 9-12a H4 9-12a	**Concept 1 Sectionalism** **Essential Questions:** • How did the issue of sectionalism lead to the Civil War? • To what extent did differing opinions on slavery as well as the institution's expansion become a deciding factor towards war? **Concept 2 Causes of the Civil War** **Essential Questions:** • To what extent was slavery the primary cause of the Civil War? • What did a federal union of states mean politically and socially before and after the Civil War? **Concept 3 Fighting the War /Turning Points** **Essential Questions:** • Why are the Battle of Gettysburg and Siege of Vicksburg considered the military turning points of the civil war? • How did the political actions of President Lincoln affect the outcome of the war? • Was it inevitable that the North would win the war? **Concept 4 Reconstruction and Impact** **Essential Questions:**	Formative Data collection and analysis of relationship between cotton gin and need for slaves Map activity and comparison- Missouri Compromise, Kansas Nebraska Act, Compromise of 1850 Document study and timeline creation Chapter readings and questions Summative Identify abolitionists arguments writing Illustrate a map of Anaconda plan Compare/contrast pre-war slave codes with post-war Codes Test Formative Sample Question To what extent was slavery the primary cause of the Civil War? Summative Sample Question How have changes during Reconstruction made a lasting impact on America? Summative Performance Task

		• How have changes made during the Reconstruction made a lasting impact on America? • How did the Civil War and Reconstruction positively impact the lives of former slaves, women, and landless tenants in the US? • To what extent have the issues surrounding the Civil War yet to be resolved? **Content Specific Vocabulary** Slave Codes, Underground Railroad, Compromise of 1850, Fugitive Slave Act, Bleeding Kansas, Dred Scott v. Sanford, election of 1860, carpetbaggers, sharecroppers	Participate in a peace summit between North and South and agree on a peace resolution
Westward Expansion	H1 6-8a 9-12a H2 6-8a 6-8b 9-12a 9-12b H3 9-12a H4 9-12a	**Concept 1 Migration** **Essential Questions:** • Who migrated West and what problems did they experience? • How did the experiences of the settlers impact their successes or failures? • Why did different groups of people have such varied experiences? **Concept 2 Western Settlements** **Essential Questions:** • How did the environment of the West impact the success of the settlers? • How did the migration of people bring about change in the West? **Concept 3 Populism** **Essential Questions:** • Why did so many farmers support populism? • How and why was the plight of the American farmer so different from that of other Americans?	Formative Primary Sources Activity- Letters Home Demographic chart- who went west? Photo and narrative analysis of Native Americans after expansion by settlers Chapter readings and questions Political carton and speech analysis Populist party outline Summative Town Meeting- Interstate Commerce Act Test Formative Sample Question Who migrated West and what problems did they experience? Summative Sample Question How can technological innovations change society?

		Concept 4 Industrialization in the West **Essential Questions:** • How can technological innovations change society? • Why did the agricultural innovations and technological developments impact groups of people in different ways? • How did the existence of the frontier impact the technological development of the US? **Content Specific Vocabulary** Gold Rush, Homestead Act, Transcontinental Railroad, Battle of Big Horn, Interstate Commerce Act,	Summative Performance Task Create a political cartoon from the perspective of a farmer in support of populism.
Industrialization	H1 6-8a 9-12a H2 6-8a 6-8b 9-12a 9-12b H3 9-12a H4 9-12a	**Concept 1 Urban life** **Essential Questions:** • How did immigration and industrialization shape urban life? • How did the rapid industrialization of the Gilded Age create economic, social, and political change in the US? **Concept 2 Industry Leaders** **Essential Questions:** • What characteristics were vital to the success of industrial leaders of the Gilded Age? • How did captains of industry accumulate wealth and power? • Should there be government limits on the accumulation of wealth? **Concept 3 Labor Unions** **Essential Questions:** • What social, economic, and political factors led to the formation of labor unions?	Formative Debate melting pot theory Graph immigration patterns Chapter readings and notes Letters to the editor Summative Persuasive writing on work reform Man of the Year Dinner Gilded Age Museum Exhibits Test Formative Sample Question How did captains of industry accumulate wealth and power? Summative Sample Question How did immigration and industrialization shape urban life?

		• Were labor unions effective in meeting the political, economic, and social needs of laborers? • How effective were labor unions in improving the lives of American workers? **Concept 4 Government Role** **Essential Questions:** • How did the government's role in economic and political affairs change during this era? • To what extent did industrialization affect the relationships between government, business, and the worker? **Content Specific Vocabulary** Jacob Riis, sweatshops, Standard Oil Company, Gilded Age, Pullman Strike, Homestead Strike, Pendelton Act, Mugwumps	Summative Performance Task Create exhibit for the Gilded Age museum that shows the perspective form the upper and lower class.

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SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors Literature Cycle I: American Literature **GRADE: 11/12**

Unit	Standards	Unit Concept/Essential Questions	Assessments
1 **Colonial American Literature, 1600-1700:** **What defines an American?** (Summer & MP1)	RL. 11-12 1 RL. 11-12 3 RL. 11-12 4 RL. 11-12 7 RL. 11-12 9 RL. 11-12 10 RI. 11-12 1 RI. 11-12 2 RI. 11-12 5 RI. 11-12 6 RI. 11-12 8 RI. 11-12 9 RI. 11-12 10 W. 11-12 1 W. 11-12 4 W. 11-12 7 W. 11-12 10 L. 11-12 1a L. 11-12 2 L. 11-12 6 SL. 11-12 1 SL. 11-12 4	**Essential Questions** **A – What Defines an American? (Summer Reading)** • What drives immigration to America? • How are historic, cultural, economic, religious, and ethnical aspects of a society reflected in early American literature? • How was connotation used in early American literature to promote the beliefs and values of the early settlers? **Example texts:** **"Enrique's Journey" (Sonia Nazario) (Nonfiction Text, Summer Reading) ISBN 0812971787** **B - Founding documents** • What literary techniques are present in our earliest American writing? • How are historic, cultural, economic, religious, and ethnical aspects of a society reflected in early American literature? • How was connotation used in early American literature to promote the beliefs and values of the early settlers? **Example texts:** "A Hymn to the Evening" (Phillis Wheatley) "On Being Brought from Africa to America" (Phillis Wheatley) "The Trials of Phyllis Wheatley" (Henry Louis Gates, Jr.) **C - Puritan speeches and sermons** • How do diction and form impact the effectiveness of a speech? • How are the persuasive elements of writing used in a work intended for oral presentation?	Structured discourse protocols - formative Dramatic reading of a play – formative Journals – formative Objective Summary - formative Quizzes – summative 1A Journal (summer writing) – formative 1A Essay (summer writing) – formative 1A Exam – summative 1A Performance Task - summative 1B Exam - summative 1C Performance Task: Speechwriting & presentation – summative 1D Analytic Essay – formative 1D Research Essay – summative Example of Formative Journal Question: Re-read "On Being Brought from Africa to America." Select 5-10 words that have a strong connotation. What other word choices could have been used that would have maintained the same connotation? Do these other word choices create the same emotional response? Why or why not? Example of Summative Research Prompt: Consider the similarities of the witch hunts of Salem and the McCarthy trials. Identify a modern witch hunt that shares these similarities. Research this topic and write an expose article that

	SL. 11-12 6	**Example text:** "Sinners in the Hands of an Angry God" **D – Drama and historical context** • How do we analyze and critique dramatic texts? • What literary elements are utilized in drama? • How do works of historical fiction connect the past and present? **Example texts:** **"The Crucible" (text & film) ISBN-10: 0142437336** Articles: Puritan History **CONTENT-SPECIFIC VOCABULARY**: poetics, void, succumb, emigration, immigration, colonial, semantics, sermon; additional text-specific vocabulary.	exposes the truth about the situation Examples of Performance Tasks: Through interviews and research, identify when and why your own family emigrated to the United States. What dream or need inspired that journey, and was it realized? Create a presentation of artifacts to share with the class. You will be presenting a speech to our class 'Town Council.' Choose an issue that you are passionate about, such as environmentalism, public education, or a local political issue. Plan, write, and present a persuasive, 2-3 minute speech that addresses your issues and convinces us to vote in your favor.
2 **The Earliest Americans, 1750-1800:** **What defines an American?** (MP2)	RL. 11-12 1 RL. 11-12 6 RL. 11-12 10 RI. 11-12 3 RI. 11-12 4 RI. 11-12 10 W. 11-12 3 W. 11-12 4 W. 11-12 5 W. 11-12 10	**A – American Indian Myths & Legends** • What defines a myth, legend, parable, and fable? • How do the creation stories of the American Indians differ in content and structure from those of the Puritan settlers? **Example texts:** "The World on the Turtle's Back" PBS: Native American Myths "Native American Myths & Legends" (excerpts) "Yellow Woman and a Beauty of the Spirit" (Leslie Marmon Silko) **B – Author Study: Sherman Alexie** • How are American Indian myths presented in modern times? • How are American Indians represented in modern literature?	Structured discourse protocols - formative Re-writing activity – formative Journals – formative Quizzes – summative 1A Essay - summative 1B Performance Task – Adaptation & Performance - summative 1B Exam – summative 1B Collaborative Writing - summative Example of Formative Journal Questions: What is a myth, legend, fable, or parable that is entwined in your own personal history? How does it impact your lens, perspective, or positionality when you read?

	L. 11-12 1 L. 11-12 3 L. 11-12 6 SL. 11-12 1 SL. 11-12 2 SL. 11-12 6	• How does positionality impact the reading of American literature representing minorities? **Example texts:** "The Absolutely True Diary of a Part-Time Indian" (novel) "Indian Killer" (novel) "The Joy of Reading: Superman and Me" (essay) "How to Write the Great American Indian Novel" (poem) "The Facebook Sonnet" (poem) "Smoke Signals" (film adaptation) **CONTENT-SPECIFIC VOCABULARY**: myth, legend, fable, parable, adaptation, evaluation, positionality; text-specific vocabulary	One of the important elements of the novel is the importance of dreams. Many dreams are realized; some dashed. Reflect upon your own dreams, past and present. Are dashed dreams just as important as those that are realized? Example of Summative Essay Prompt: Arnold experiences judgment from both his tribe and white society. Throughout the novel, he has an opportunity to reflect on these judgments, and the fairness or unfairness of them. Connect his community to those that surround you, comparing and contrasting his experiences to your own, and draw conclusions about the ways in which you are both fairly and unfairly judged. Example of Performance Task: You have been selected to adapt an American myth, legend, or short story into a one-act play. Choose, adapt, script, and perform your play for our audience. *Student collaboration – reservation school pen pals
3 **Mini-Unit - American Transcendentalism, 1820-1850:**	RL. 11-12 1 RL. 11-12 6 RL. 11-12 10 RI. 11-12 3 RI. 11-12 4 RI. 11-12 10	**A - The Transcendentalist Movement** • How are the concepts of logos, pathos, and ethos used by American writers? • How do belief systems and politics impact the literature of the time? • How did Transcendentalist writing impact the development of the American justice system?	Structured discourse protocols - formative Re-writing activity – formative Journals – formative Objective Summary - formative Quizzes – summative 1A Essay - summative 1A Personal values essay - summative

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors Literature Cycle I: American Literature **GRADE: 11/12**

What defines an American? (MP2)	W. 11-12 3 W. 11-12 4 W. 11-12 5 W. 11-12 10 L. 11-12 1 L. 11-12 3 L. 11-12 6 SL. 11-12 1 SL. 11-12 2 SL. 11-12 5 SL. 11-12 6	• How do short fiction and short nonfiction differ in structure, theme, and use of language? Example texts: "Walden" (excerpts) (Thoreau) "Civil Disobedience" (Thoreau) "Nature" (Emerson) "Self-Reliance" (Emerson) "12 truths I learned from life and writing" Anne Lamott TED Talk "Social Media Is Killing Discourse Because It's Too Much Like TV" by Hossein Derakhshan "The American Dream, Quantified at Last" by David Leonhardt "What it feels like to be the last generation to remember life before the internet" by Leo Mirani **CONTENT-SPECIFIC VOCABULARY**: transcendentalism, philosophy, naturalism; text-specific vocabulary	1A Performance Task - summative Example of Formative Journal Question: Given [specific quotes], reflect upon how this statement could apply to modern culture. Example of Summative Essay Prompt: Thoreau talks about the two sides of man's dual nature. Identify an element of yourself in which you exhibit a dual nature. In a 3-4 page essay, explain this dual nature and how you plan to embrace or change this about yourself in the future, and why. Example of Performance Task: Curate and present a digital art exhibit of at least 15 examples of identified, cited works of art that represent an aspect of transcendentalism, and for each include a statement explaining the relationship between the work and transcendentalism, as well as a quote from a transcendental author that serves as evidence for your explanation.

4 **Industrialized America, 1875-1925:** **What defines an American?** (MP 3)	RL. 11-12 1 RL. 11-12 5 RL. 11-12 10 RI. 11-12 3 RI. 11-12 7 W. 11-12 3 W. 11-12 4 W. 11-12 6 L. 11-12 1 L. 11-12 2 L. 11-12 3 SL. 11-12 2 SL. 11-12 4 SL. 11-12 5	**A - Literature as a Voice of the People** • How do authors use texts to examine social changes and themes? • What are the common themes of American literature? • How are social ideals and conflicts represented through innuendo, metaphor, and stereotypes? **Example texts:** Short Stories & poems such as Paine's "Common Sense," readings about the first Webster's dictionary, "American Cookery," and by authors such as Wharton, Eaton, James Weldon Johson, Frost, Gertrude Stein, Bierce, Lowell, Sherwood Anderson, Wilkins, Freeman, and Oscar Micheaux 101 Great American Poems, ISBN-10: 0486401588 100 Great Short Stories, ISBN-10: 0486790215 **B – Historical Contexts** • What differentiates historical non-fiction from historical fiction? • How can a reader determine the trustworthiness of a text's source material? • How does the inclusion of artifacts affect the impact of a text? **Example texts:** "The Jungle" (Sinclair) "Gangs of New York" (Asbury) Must be the Vintage Publisher reprint edition, (2008), ISBN-10: 0307388980 The Museum of Extraordinary Things (Alice Hoffman) ISBN-10: 1451693575 "Maggie, Girl of the Streets" (& Other Stories About New York) (Crane)	Structured discourse protocols - formative Re-writing activity – formative Journals – formative Quizzes – summative 1A Essay – summative 1A Exam - summative 1B Performance Task – - summative 1B Exam - summative Example of Formative Journal Question: What common themes emerge in turn-of-the century literature? Example of Summative Essay Prompt: How has the concept of the American Dream evolved in literature as America has become industrialized? Example of Performance Task: After researching a family who lived at the turn of the century, curate a collection of artifacts that may have belonged to them, and provide evidence for the importance of each object through a connection to the literature of the time.

		"The Great Gatsby" (Fitzgerald) "Main Street" (Lewis) "Fast Food Nation" (Schlosser) CONTENT-SPECIFIC VOCABULARY: symbolism, aesthetics, satire, connotation, denotative, industrialization, representational; text-specific vocabulary	
5 **WWII America: What defines an American?** (MP4)	RL. 11-12 1 RL. 11-12 3 RL. 11-12 10 RI. 11-12 3 RI. 11-12 7 W. 11-12 3 W. 11-12 6 W. 11-12 7 L. 11-12 1 L. 11-12 2 L. 11-12 3 SL. 11-12 2 SL. 11-12 4 SL. 11-12 5	**A – Literature as a Mirror of Conflict** • How does literature mirror cultural and political changes in society? • How did the economic, social and war issues of the early twentieth century affect the literature written during this era? • How can a reader separate propaganda from truth? • How are social ideals and conflicts represented through symbolism, figurative language, and representative characterizations? • How are different cultural experiences represented by American literature? **Example texts:** Short Stories & poems could include Steinbeck, Hemingway, Fitzgerald, O'Henry, Hughes, London, Anderson, Cheever, Weisel, Faulkner, Steinbeck. "A Separate Peace"(John Knowles) ISBN-10: 0743253973 "When the Emperor Was Divine" (Julie Otsuka) ISBN-10: 0385721811	Structured discourse protocols - formative Journals – formative Quizzes – summative 1A Essay – summative 1A Exam - summative 1B Performance Task – - summative Example of Formative Journal Question: What examples of propaganda do you recall being exposed to through the media? How was it presented? Example of Summative Essay Prompt: Did World War II America offer the same experience and opportunities to all Americans? Using our texts, provide evidence for your argument. Example of Performance Task: Following the standards given for participation in the Library of

		B – Literature vs. Reality • How are literary representations of war different from the reality? • How do personal experiences become part of a common text? Example texts: "The Things They Carried" (Tim O'Brien") **CONTENT-SPECIFIC VOCABULARY**: propaganda, name-calling, glittering generality, card-stacking, testimonial, interview, bandwagon, smokescreen, internment; text-specific vocabulary	Congress Living History Project, interview a veteran for inclusion in their library. Then compare their experience to one represented in literature about the same conflict, and compose a profile and essay reflecting upon the similarities and differences for inclusion in a collaborative publication.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Driver Education **GRADE 10**

TEACHER'S NAME: Stephen Oscar **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Driver Education **GRADE 10**

Unit	Standards	Unit Concept/Essential Questions	Assessments
		Driver Education Statewide Curriculum – Revised 2015	Section 1,2,3,4,5 Quizzes - Formative
			Section 1,2,3,4,5, Tests - Summative
			Portfolio of Student Work – Rubric
			Four Research Papers- Summative
			100 question Division of Motor Vehicles State Final Exam – 70% minimum passing score
			Must earn 5 academic credits at the conclusion of the prior or current marking period in order to receive the "Blue Certificate"

TEACHER'S NAME: Stephen Oscar **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: U.S. History **GRADE: 8**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Colonies to Country	Civics !b Civics 2b Econ 1a History 1a History 3a CC.8.5.6-8.A. CC.8.5.6-8.B. CC.8.5.6-8.F. CC.8.5.6-8.G. CC.8.5.6-8.H. . CC.8.6.6-8.B.	Developing Regions • Why do countries colonize? • How did geography impact the economy of the colonial regions? • How did the Atlantic Slave Trade evolve and impact global trade? Gaining Independence • What events and ideas led to American Revolution? • Why is the Declaration of Independence such a powerful document? • What effects did the Revolution have on the global economy? Foundations of our Government • What principles of the Constitution allow it to be a living document? • How does our system honor majority rule while protecting minority rights? Content Specific Vocabulary specialization, scarcity, mercantilism, popular sovereignty, propaganda, firebrand, federalism, checks and balances, capitalism, profiteer, contextualization, corroboration, eminent domain, due process	The Firebrands – Wanted Poster project - formative INB Checks - formative Causes of War Quiz - formative Unit Test – summative Formative Sample Question: What evidence can you find in the graph above that would support Britain's need to establish a system of mercantilism? Summative Sample Performance Task Economics of Colonial Regions - Investment Simulation – students form investment companies and attempt to earn capital by investing in various products using geographic and cultural knowledge gained about each colonial region.

TEACHER'S NAME: Janet Owens **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: U.S. History **GRADE: 8**

TEACHER'S NAME: Janet Owens **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: U.S. History **GRADE: 8**

Sectionalism and the Civil War	Civics 1a Civics 1b Civics 1c Hist 1a Hist 2a Hist 3a CC.8.5.6-8.A. CC.8.5.6-8.F. CC.8.5.6-8.G. CC.8.5.6-8.J.	Slavery, Sectionalism, and Civil War • How did the southern economy become so dependent on slavery? • What changes led to the growing differences between the northern and southern regions? • What conditions led to the growth of the Abolition Movement? Causes of Conflict • What political, economic, and social conditions led to the Civil War? • What actions were taken to avoid war? Effects of War • What economic impact did the war have on the southern region and the country as a whole? • How was southern culture changed? • What steps did the U.S. Government take to ensure that this would never happen again? • What effects do we still see today? Industrial Age • How did the Industrial Revolution impact this war? (new technology, medical advancements) • How did these new innovations affect the U.S. economy? Content Vocabulary	*To Be A Slave* discussion questions – formative INB Checks - formative Causes of War Quiz– formative Unit Test – summative Formative Sample Question – Create a CSET response to agree or disagree with this statement: "Without the invention of the cotton gin in 1793, the American Civil War would have never occurred."

TEACHER'S NAME: Janet Owens **6/17**

		Sectionalism, platform, sovereignty, nullification, secession, anti-bellum, sharecropping, chattle, abolition, suffrage	

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CURRICULUM FRAMEWORK

COURSE: U.S. History **GRADE: 8**

TEACHER'S NAME: Janet Owens **6/17**

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CURRICULUM FRAMEWORK

COURSE: Honors Anatomy **GRADE: 11 and 12**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1- THE HUMAN BODY: AN ORIENTATION Chapter 1	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2 HS-LS1-3	Essential Questions • What is anatomy? • What are the requirements for human life? Learning Objectives Student will be able to… 1. Define the term anatomy. 2. Define and use common Latin roots, prefixes and suffixes. 3. Describe how observation is used to see the sizes and relationships of body parts. 4. Name the levels of structural organization the make up the human body and explain how they are related. 5. Define homeostasis and explain its importance in maintaining life. 6. Use proper anatomical terms to describe body directions, surfaces, & planes. 7. Locate the major body cavities and list the chief organs in each cavity. 8. Name the organ systems of the body and describe the major functions of each. Content Specific Vocabulary Anatomy, Observation, Homeostasis, Levels of Organization, Atom, Molecule, Cell, Tissue Organ, Organ System, Organism, Directional terms, surfaces and planes,Body Cavities	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Virtuvian Man Lab- Student analyze their own body symmetry and calculate body proportions and ratios using standard body-metrics data. Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 1 Unit test Performance Tasks:

TEACHER'S NAME: Jennifer Couch **6/17**

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COURSE: Honors Anatomy **GRADE: 11 and 12**

			Anatomy Man Project- Students create a model human and then create a story based on anatomical terms they have randomly chosen from a bag and read the story to the class.
Unit 2- BASIC CHEMISTRY Chapter 2	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-PS1-1 HS-PS1-2 HS-LS1-6	Essential Question: • What is the relationship between matter and energy as it relates to the human body? Learning Objectives: Students will be able to… 1. Differentiate between matter and energy. 2. Explain the relationship between subatomic particles and elements. 3. List the 4 elements that make up the bulk of body matter. 4. Recognize that chemical reactions involve the interaction of electrons to make and break chemical bonds. 5. Differentiate between ionic, covalent, and hydrogen bonds 6. Compare and contrast synthesis, decomposition, single-replacement, and double replacement reactions. 7. Describe the importance of selected salts in body functioning. 8. Distinguish between organic and inorganic molecules. 9. Name and describe the 4 major classes of macromolecules including their building block molecules and their major functions. 10. Describe the roles of water in body functioning. 11. Explain the role of enzymes.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Great Ion Bead Game Ion Speed Date Activity McMush Murder Lab Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point

		Content Specific Vocabulary: Matter, Energy, Atom, Proton, Neutron, Electron, Isotope, Ion, Cation, Anion, Chemical reactions, Covalent bond, Ionic Bond, Hydrogen Bond, Synthesis, Decomposition, Single Replacement, Double, Replacement, Organic, Inorganic, Macromolecule, Carbohydrate, Protein, Lipid, Nucleic, Acid, Activation energy, Reactants, Products, Enzymes, Endothermic, Exothermic, Active site, Denature, ATP	presentation) Summative: Tests/ Labs: Chapter 2 Unit Test Performance Tasks: Present Findings of McMush Murder Lab
Unit 3- CELLS AND TISSUES Chapter 3	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2	Essential Questions: • How do cells and the organelles within them work together to form the basis of all life? • How and why do cells differentiate? • What are tissues and how are they classified? Learning Objectives: Students will be able to… 1. Define, identify, and explain the function of a typical animal cell and its organelles. 2. Describe the processes that move substances into and out of cells. 3. Describe the process of DNA replication and mitosis 4. Describe the functions of the 3-types of RNA & the process of protein synthesis. 5. Name and contrast the 4 major types of tissue. 6. Describe the chief locations of the various body tissue types. 7. Describe the process of tissue repair. 8. Describe the characteristics of a neoplasm.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Genetic Code Relay Game Cell Specialization Virtual Lab Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at

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COURSE: Honors Anatomy **GRADE: 11 and 12**

		Content Specific Vocabulary: Cell, Organelle, Homeostasis, Passive transport, Diffusion, Osmosis, Hypertonic, Hypotonic, Isotonic, Facilitated diffusion, Active transport, Molecular pumps, Endocytosis, Exocytosis Differentiation, Daughter cells, Sister chromatids, Centrioles, Spindle fibers, Cell cycle, Interphase, Mitosis, Prophase, Metaphase, Anaphase, Telophase, Cytokinesis, Cleavage furrow/ Cell plate, Cancer, Carcinogen, Malignant, Benign, Tissues, Connective tissue, Nervous tissue, Muscle tissue, Epithelial tissue, Regeneration, Fibrosis	home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 3 Unit Test Performance Tasks: Students create a “secret code” using an amino acid sequence- Other students use the codon chart to try to solve.
Unit 4- SKIN AND BODY MEMBRANES Chapter 4	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2	Essential Question: • What are membranes? • How does the structure of a membrane impact its function? • What is the function of skin? • How does the structure of skin impact is function? Learning Objectives: Student will be able to: 1. List the general functions of the 4 types of membranes and describe their location in the body. 2. Describe the functions of the integumentary system. 3. Name and describe the functions of the major proteins of the integumentary system.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Touch- Test Lab- Student create probes and test the sensitivity of different body regions

TEACHER’S NAME: Jennifer Couch **6/17**

		4. Locate and describe selected skin layers, structures, and derivatives. 5. Describe the cause and pathology of selected skin disorders. Content Specific Vocabulary: Membrane, Cutaneous, Mucous, Serous, Synovial, Integumentary System, Epidermis, Dermis, Sebaceous gland, Hair follicle, Melanin, 1st, 2nd, 3rd degree burns, Rule of Nines, Basal cell carcinoma, Squamous cell carcinoma, Melanoma	How Much Skin Do You Have- Student take body measurements to complete skin surface area calculations – Important for the Rule of Nines Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 4 Unit Test Performance Tasks: • Skin disease and disorder research presentations
Unit 5- THE SKELETAL SYSTEM	*Next Generation Science Standards by NSTA and*	Essential Question: • What are the major divisions of the skeletal system and how do we differentiate between them. • What are the major structures of long bones?	The following assessments will provide evidence of student learning: Formative:

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Chapter 5	*Delaware Department of Education:* HS-LS3-1 HS-LS3-2	• What are the major types of joints? • What are ways to increase bone density and integrity? • What role do age and gender have in bone growth and formation? Learning Objectives: Student will be able to: 1. Identify the subdivisions of the skeleton as axial or appendicular. 2. List and describe the major functions of the human skeleton. 3. Classify bones on the basis of shape and relate the shape to the function of a bone. 4. Describe and identify the types of bone markings and their functions. 5. Identify all 206 bones of a human skeleton in diagram, model, & disarticulated skeletons. 6. When given a picture or x-ray be able to name and describe various types of fractures. 7. Describe 3 major categories of joints; compare the amount of movement allowed by each. 8. Distinguish between male, female, infant, child, & adult skeleton samples and fragments. 9. Describe the process of bone formation and bone aging. Content Specific Vocabulary: Axial, Appendicular, Osetocyte, Osteoblast, Osteoclast, Osteoporosis Articulation, Ligament, Fracture, Dislocation, Joint, Scoliosis, Lordosis, Kyphosis, Osteoporosis	Daily Vocab Slam quizzes via Schoology • Classwork/Labs: Unearthing 17th Century Chesapeake- A Forensic Science “Bone” Lab • Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: • Tests/ Labs: Chapter 5 Unit Test Disarticulated Skeleton Practicum Performance Tasks: What do these bones tell? Given a set of bones and historical clues student create a plausible “life-story” for the

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COURSE: Honors Anatomy **GRADE: 11 and 12**

			person the bones belong to.
Unit 6- BLOOD Chapter 10	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2	Essential Question: • What are the structures and functions of blood? Learning Objectives: Student will be able to: 1. Describe the transport and heat distributing functions of the blood. 2. Describe the composition of blood plasma. 3. Name the formed elements of the blood and describe the major functions of each. 4. Describe causes, symptoms, & problems associated w/ anemia, leukemia, & hemophilia. 5. Explain the basis for a blood transfusion reaction. 6. Name the sites and cells involved in blood cell formation. Content Specific Vocabulary: Plasma, Formed elements, Leukocyte, Erythrocyte, Thrombocyte, Hematopoesis, Anemia, Polycythemia, Leukopenia, Leukocytosis, Hemocyoblast, Hemophilia, ABO blood typing, Rh factor Jaundice	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Blood typing lab- Using synthetic blood students determine blood types using the ABO- Rh blood typing systems Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 5 Unit Test

TEACHER'S NAME: Jennifer Couch **6/17**

			Genetics of Blood Quiz Performance Tasks: Given specific blood type genotypes students will be able to calculate and predict blood types of offspring
Unit 7- THE CARDIOVASCULAR SYSTEM Chapter 11	*Next Generation Science Standards by NSTA and Delaware Department of* Education: HS-LS2-1 HS-LS2-2	Essential Question: • What are the structures of the cardiovascular system? • How does the heart pump blood? • What are the 3 types of vessels that make up the cardiovascular system and what are their general functions? Learning Objectives: Student will be able to: 1. Trace the path of blood through the heart & lungs naming chambers, valves, & vessels. 2. Describe the cardiac cycle. 3. Describe the influence of selected factors on cardiac output. 4. Describe the pathway & parts of impulses through the intrinsic conduction system. 5. Explain what information can be gained from an electrocardiogram. 6. Describe normal blood pressure and list factors that affect it. 7. Describe the exchanges that occur across capillary walls. 8. Locate, name, and identify areas served by each of the arterial branches of the aortic arch.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Heart Dissections Heart Rate Lab- Learn how to take radial or corroded pulses and investigate factors that influence heart rate including exercise and meditation Homework:

		9. Locate and name selected arteries and veins and describe the areas served by each. Content Specific Vocabulary: Cardiovascular system, Heart, Artery, Vein, Capillary, Pulmonary circulation, Systemic Circulation, Intrinsic conduction system, Systole, Diastole, Stroke volume, Cardiac cycle, Murmur, Blood pressure, Pulse, Hypertension, Atherosclerosis	Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 7 Unit Test Performance Tasks: Students will be able to take a patient's blood pressure using a sphygmomanometer
Unit 8 - THE LYMPHATIC SYSTEM Chapter 12	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1	Essential Question: • What is the lymphatic system and what is its role in human health? • What are the structures of the lymphatic system? • What are other body defense mechanisms and what is their role in human health? Learning Objectives: Student will be able to: 1. Name the two major types of structures composing the lymphatic system & explain how the lymphatic system is functionally related to the cardiovascular and immune systems. 2. Describe the composition of lymph and explain its formation and transport. 3. Identify location & function of tonsils, nodes, thymus, Peyer's patches, & the spleen.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Hand Sanitizers – Helpful or Harmful Lab- Students design a lab investigation

	HS-LS2-2	4. Describe the protective functions of skin, mucous membranes, phagocytes, natural killer cells, fever, interferon and gastric juice. 5. Describe the role of selected defensive structures & responses as specific or nonspecific. 6. Describe the role of T cells and B cells in the immune response. 7. Name the types of acquired and natural immunity and describe the source of each. 8. Describe the function of selected cells involved in the immune response. 9. Name the cause and describe the pathology of selected diseases. Content Specific Vocabulary: Lymphatic system, Lymph, Lymph nodes, Tonsils, Thymus, Peyer's patches, Spleen, Edema, Pathogen, Phagocytes, Inflammatory process, Fever, Antigen, Hapten, Lymphocytes, B cells, T cells, Macrophage, Antibodies, Active immunity, Passive immunity, Immunodeficiency, Allergies, Autoimmune disease	to analyze the effectiveness of various soaps and hand sanitizer and then draw conclusions about the implications of the data they collect. Who's Immune? – Students investigate diseases like Ebola, Black Death, Typhoid fever and HIV to gain an understanding of how diseases are spread and how one can become immune to them. (Natural or Acquired immunity) Also, students will be able to pinpoint the evolutionary cause of "super bugs" like MRSA. Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs:

			Chapter 8 Unit Test Performance Tasks: Students present their "Who's Immune" research. Student will model the proper hand washing technique to decrease the spread of disease.
Unit 9- THE MUSCULAR SYSTEM Chapter 6	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1 HS-LS2-2	Essential Question: • What is the general structure and function of muscles? • What are the 3 types of muscles and how can one differentiate between them? • What is the major smooth muscle in the human body? • What are the major skeletal muscles in the human body? Learning Objectives: Student will be able to: 1. Identify similarities, differences, and locations of the 3 types of muscle. 2. Link "origin, insertion, prime mover, antagonist, synergist, & fixator" to muscle actions. 3. Demonstrate and identify the different types of body movements 4. Name and locate the major muscles of the human body. 5. Describe the origin, insertion, and action of selected muscles. 6. Describe the structures that form the anatomy of a muscle. 7. Name the primary muscle proteins.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Gross Skeletal Muscle Identification Lab Bust-a-Move: Students create a hand-shake or dance that uses all of the major body movements. Homework:

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COURSE: Honors Anatomy **GRADE: 11 and 12**

		Content Specific Vocabulary: Muscle fiber, Skeletal muscle fiber, Voluntary, Involuntary, Straitions, Endomysium, Perimysium, Epimysium, Tendons, Smooth muscle, Cardiac muscle, Sarcolemma, Myofibril, I band, A band, Sarcomeres, Myofilaments, Actin, Myosin, Neurotransmitter, Acetylcholine (Ach), Action Potential, Flexion, Extension, Rotation, Abduction, Adduction, Circumduction, Dorsiflextion, Plantar flexion, Inversion, Eversion, Supination, Pronation, Opposition, Fixator, Synergist, Prime mover, Antagonist, Origin, Insertion	Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 9 Unit Test Skeletal Muscle ID Quiz Performance Tasks: Bust-a-Move: Students present the hand-shake or dance they created that uses all of the major body movements.
Unit 10- SPECIAL SENSES Chapter 8	*Next Generation Science Standards by NSTA and Delaware Department of Education:*	Essential Question: How do special senses respond to different types of energetic stimuli involved in vision, hearing, balance, smell, and taste? Learning Objectives: Student will be able to: 1. Identify the accessory structures of the eye in a model or diagram and list their functions. 2. Name the eye tunics and describe the functions of each. 3. Explain the difference between rod and cone function.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs:

	HS-LS2-1 HS-LS2-2	4. Trace pathway of light through the eye to the retina & visual pathway to the optic cortex. 5. Identify the structures & functions of the external, middle & internal ear. 6. Describe the location, structure, and function of the olfactory and taste receptors. Content Specific Vocabulary: Special sense receptors, ANATOMY OF THE EYE- External and Accessory Structures: eyelid, medial and lateral commissure, canthus, eyelashes, tarsal glands, conjunctiva, lacrimal, lysosome Extrinsic and external eye muscles, Internal Structures: Eyeball, Tunics, Sclera, Cornea, Fibrous Layer, Vascular layer, Choroid, Ciliary zonule, Iris, Pupil, Sensory layer, Retina, Photoreceptors, Rods, Cones, Optic nerve, Blind spot, Optic Disc, Fovea centralis, Lens, Cataracts, Glaucoma ANATOMY OF THE EAR- Mechanoreceptors, External Ear- Auricle, Pinna, Cerumen, External acoustic meatus, tympanic membrane, Middle Ear- Tympanic cavity, Oval window, Round window, Pharyngotympanic tube, Ossicles, Osseous labyrinth, Cochlea, Vestibule, Semicircular canals, Static and Dynamic equilibrium, Hair Cells TASTE BUDS AND THE SENSE OF TASTE- Taste buds, Papillae, Circumvallate and Fungiform papillae, Gustatory Cells, Taste pore, Glossopharyngeal, Vagus	Eye dissections Can You Be A Fighter Pilot? – Student test their visual acuity, peripheral vision and balance using standardized tests. Colorblindness Tests Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 10 Unit Test Eye Anatomy Quiz Ear Anatomy Quiz Tongue Anatomy Quiz Performance Tasks: Hearing Safety Public Safety

			Announcement – Post to Hawk News
Unit 11- THE NERVOUS SYSTEM Chapter 7	Next Generation Science Standards by NSTA and Delaware Department of Education: HS-LS2-1 HS-LS2-2	Essential Question: How does the nervous system maintain body homeostasis with electrical signals; provide for sensation, higher mental functioning, and emotional response? Learning Objectives: Student will be able to: 1. List the general function of the nervous system. 2. Explain the structural and functional classifications of the nervous system. 3. Describe the major parts of the central nervous system and peripheral nervous system. 4. State the functions of neurons and neuroglia. 5. Describe the functions of the major regions of the cerebral hemispheres, diencephalons, brain stem, and cerebellum & identify their location on a human brain model or diagram. 6. Describe the general structure and function of a nerve. 7. Name and describe protective structures of the central nervous system. 8. Describe spinal cord structure. 9. Describe the areas served by selected plexuses and nerves. 10. Describe the electrical & chemical events involved in transmission of a nerve impulses. Content Specific Vocabulary: Nervous system, Stimulus, Sensory input, Integration, Motor output, Central nervous system, Peripheral nervous system, afferent, efferent, somatic, voluntary, autonomic, involuntary, Neuroglia, Oligodendrocytes, Asrocytes, Axon, Dendrite, Schwann cell, Axon terminal, Neurotransmitter, Synapitic cleft, Synapse, Nodes of Rnavier, Mutiple Sclerosis, Cerebral Hemisphere, Gyri, Sulci, Fissures, Lobes, Cerebrum, Cerebral cortex, Grey matter, White matter, Brain stem, Midbrain,	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Brain Dissections Brain Hat- Student make a model of the basic structures of the brain that they can wear as a hat. Reaction Rate Lab- Students investigate reaction rate and factors such as listening to music and texting that effect reaction rate Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point

		Medulla oblongata, Cerebellum, Huntington's disease, Parkinson's, Alzheimer's	presentation) Summative: Tests/ Labs: Chapter 11 Unit Test Anatomy of the Brain and Neuron Quiz Performance Tasks: Nervous System Disease Disorder Presentation
Unit 13- THE RESPIRATORY SYSTEM Chapter 13	Next Generation Science Standards by NSTA and Delaware Department of Education: HS-LS2-1 HS-LS2-2	Essential Question: How does the respiratory system supply the blood with oxygen while removing carbon dioxide? Learning Objectives: Student will be able to: 1. Name and locate the structures forming the respiratory passageway form the nasal cavity to the alveoli and describe the function of each. 2. Describe the protective mechanisms of the respiratory system. 3. Describe the mechanics of breathing. 4. Describe the various respiratory volumes and capacities. 5. Describe the process of gas exchange in the lungs and tissues. 6. Describe physical, emotional & chemical factors that influence respiratory rate and depth. 7. Describe the causes and pathology of selected respiratory disorders.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Calculating Respiratory Volume Lab Vape Debate- Is vaping better than smoking? Are vape advertisers targeting teens?

		Content Specific Vocabulary: Respiratory system, nose, Bronchi, Trachea, Lungs, Pulmonary, Pleura, Bronchioles, Alveoli, Respiratory membrane, Pulmonary ventilation, External respiration, Respiratory gas transport, Internal respiration, Diaphragm, Dead space volume, spirometer, Hypoxia, Carbon monoxide poisoning, CPD, Asthma, Hyperpnea, Apnea, Chronic Bronchitis, Emphysema, Cystic Fibrosis, IRDS, SIDS, Sleep apnea	Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 13 Unit Test Performance Tasks: Respiratory System Disease Disorder Presentation
Unit 14 - THE DIGESTIVE SYSTEM Chapter 14	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1	Essential Question: • What are the structures of the digestive system? • How does the digestive system break down ingested food into particles small enough to ab absorbed into the blood? Learning Objectives: Student will be able to: 1. Locate, name, describe the structure, and describe the functions of organs and accessory organs of the digestive system. 2. Describe the composition and functions of saliva, gastric juice, and bile. 3. Describe & locate the villi in the digestive tract & explain how they aid digestive process.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Digestive System Puzzle Model- Students are given the digestive system

	HS-LS2-2	4. Describe the source and digestive functions of selected hormones and enzymes. 5. Name the end products of protein, fat, and carbohydrate digestion. Content Specific Vocabulary: Chemical digestion, Mechanical digestion, Alimentary canal, Gastrointestinal (GI) tract, Mastication, Mouth, Esophagus, Pharynx, Stomach, Small intestine, Large intestine, Sphincter, Villi, Microvilli, Peristalsis, Bolus, Chyme, Liver, Pancrease, Gall bladder, Bile, Duodenum, Jejunum, Ileum, Appendix, Colon, Rectum, Cecum, Anal canal, Salivary glands, Absorption, Defecation, Ingestion, Propulsion, _Macromolecules, Carbohydrates, Monosaccharide, Protein, Amino acid, Lipid, Triglyceride, Celiac disease, IBS, Villi atrophy	organs and have to identify they and put them in the correct or and sequence Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 14 Unit Test Digestive System Anatomy Quiz Performance Tasks: Sham-Wow to Oh-No….Modeling intestinal villi disorders
Unit 15- THE URINARY SYSTEM Chapter 15	*Next Generation Science Standards by NSTA and Delaware*	Essential Question: How does the urinary system rid the body of nitrogenous wastes while regulating water, electrolyte, and acid-base balance of the blood? Learning Objectives: Student will be able to:	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via

	Department of Education: HS-LS2-1 HS-LS2-2	1. Describe the location & functions of the organs & major structures of the urinary system. 2. Identify the regions of a kidney and their functions. 3. Describe the structure and function of a nephron. 4. Describe the process of urine formation. 5. Identify mechanisms involved in regulating water, electrolytes, & pH levels of blood. 6. Describe the composition of normal urine. 7. List the causes of selected abnormal urinary components. 8. Describe three common urinary tract problems. Content Specific Vocabulary: Urinary system, Kidney, Nephron, Glomerulus, Bowman's capsule, Ureter, Urethra, Bladder, Urine, Urea, Voiding, Micturition, Incontinence, Intracellular Fluid, Extracellular fluid, Thirst mechanism, Diabetes insipdus, Polyurea, Alkalosis, Acidosis	Schoology Classwork/Labs: Urinalysis Lab- Students use simulate urine to test for diabetes, and short term and long term infections Need for Speed = Homeostatic Imbalance Debate Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 15 Unit Test Urinary System Anatomy Quiz Performance Tasks: The Obesity Epidemic CSET- Students will construct an argumentative

			paragraph using professional medical resources that argues the claim that the "convenience life-style" of America has created the obesity epidemic, which has lead to a nation-wide diabetes problem.
Unit 16 **-** THE REPRODUCTIVE SYSTEM Chapter 16	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1 HS-LS2-2	Essential Question: What is the evolutionary advantage of sexual reproduction? What are the structures, functions and purpose of the male reproductive system? What are the structures, functions and purpose of the female reproductive system? Learning Objectives: Student will be able to: 1. Explain how meiosis differs from mitosis. 2. Describe functions & locations of selected structures that form the reproductive systems. 3. Describe the processes of spermatogenesis and oogenesis. 4. Describe the phases and controls of the menstrual cycle. 5. Describe the stages of embryonic development. 6. Describe the stages of labor and how labor is initiated. 7. Explain the origin and functions of the placenta, chorion, and the amnion. 8. Describe physiological changes that occur in selected systems of a pregnant female. Content Specific Vocabulary: Sexual reproduction, meiosis, spermatogenesis, oogenesis, menstrual cycle, embryo, fetus	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Male, Female and Embryonic Development Cornell Notes Homework: Text book- Did You Get It? Questions Summative: Tests/ Labs: Chapter 14 Unit Test

			Male Reproductive System Anatomy Quiz, Female Reproductive System Anatomy Quiz

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CURRICULUM FRAMEWORK

COURSE: Economics **GRADE:10**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Economic Fundamentals	E 1 9-12a	**Concept 1 Economic Way of Thinking** **Essential Questions:** • How can you think like an economist • Why can't you get what you want? **Concept 2 Economic Systems** **Essential Questions:** • Does a society's culture affect its economic system? **Content Specific Vocabulary** Resources, goods, services, scarcity	Formative: Activity/Budget Tradeoffs Chapter 2 Text and questions Economics is Everywhere Game Summative: PPF Graphing Planning School Dance Formative Sample Question What is the system used to manage limited resources for the production, distribution, and consumption of goods? Summative Sample Question What is the difference between a trade-off and opportunity cost? Summative Performance Task Create a plan and budget for the school prom. Identify the costs and benefits and trade offs.
How Markets Work	E 1 4-5b 6-8b 9-12a	**Concept 1 Supply and Demand** **Essential Questions** • How much does price matter to consumers? • How are the prices of goods and services determined? **Concept 2 Market Equilibrium** **Essential Questions:** • Why do prices change? • How do you know when "the price is right?"	Formative: Indentured Servitude Costs Benefits Analysis Student Videos of CB Analysis Economic Systems of Athens, Sparta, Cuba, US Compare /Contrast Charts and Persuasive Writing Summative: Characteristics of Markets research,

TEACHER'S NAME:

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Economics **GRADE:10**

		Concept 3 Market Structures and Market Failures **Essential Questions:** • What happens when markets do not work perfectly? • Why do some businesses succeed and others fail? **Content Specific Vocabulary** Costs, benefits, factors of production, production possibilities frontier, demand and supply shift,	charts, and case studies Poster on Market Structures in relevant industries Test 1 Formative Sample Question What is demand elasticity and what factors influence it? Summative Sample Question What are the conditions required for perfect competition to exist? Summative Performance Task Present graphic equation poster explaining market characteristics and market structures of industry
Economic Institutions	E 2 6-8	**Concept 1 Money, Banking, Saving, and Investing** **Essential Questions:** • How should you save, spend, and invest your money? • Are the risks of savings and investment worth the rewards? **Content Specific Vocabulary** Functions and characteristics of money, fiat money, deposits, Federal Reserve Bank, diversification, investment	Formative: The Wage is Right Activity Chapter notes and questions Summative: Vacation Challenge project Formative Sample Question What is compound interest and how does it increase the rate at which your investment grows? Summative Sample Question What is the main advantage of diversification as an investment policy? Summative Performance Task Participate in game show- The Wage is

COURSE: Economics **GRADE:10**

			Right
Economics of the Public Sector	E2 9-12a	**Concept 1 Government and the Economy** **Essential Questions:** • How should the U.S. government carry out its economic roles? • Is fiscal policy an effective tool for stabilizing the economy? **Concept 2 Taxes and Taxation** **Essential Questions:** • Are taxes really necessary? • Who and what should be taxed? • To what extent do government decisions about taxation and government spending influence the state of the economy? **Content Specific Vocabulary** Regulation, merger, deregulation, poverty rate, price fixing,	Formative: Functions of government activity Trading card game Great Depression Activity Who should be taxed activity Chapter reading Summative Sugar Subsidies reading, activity and debate Uncle Sam's checkbook Test Formative Sample Question How does the government protect property rights? Summative Sample Question List and describe three incentives ownership of property provides. Summative Performance Task Participate in Congressional debate on reducing or eliminating sugar subsidies
Macroeconomics	E 2 9-12a E3 9-12a	**Concept 1 GDP** **Essential Questions:** • How do economists measure a nation's economic health? **Concept 2 Business Cycles** **Essential Questions:**	Formative: Personal Business Activity Chapter text and notes Gallery tour chart Measuring GDP activity Summative: Graphic equations of business

		• Are there predictable patterns in the economy? • Is it important for us to be able to recognize patterns in the economy? **Content Specific Vocabulary** Inflation, interest rates, business cycle, expansion, peak, contraction, trough, recession, nominal GDP, fiscal policy	structures Industry case studies Test Formative Sample Question What are the limitations of using GDP to measure economic health? Summative Sample Question What tools does fiscal policy use to stabilize the economy? Summative Performance Task Create and present a five minute speech encouraging the Federal Reserve to make changes to the interest rate.
International Trade	E4 6-8a E4 9-12a	**Concept 1 Globalization** **Essential Questions:** • How do countries conduct trade in the global economy? • Do the benefits of globalization outweigh the costs? **Content Specific Vocabulary** Comparative advantage, absolute advantage, foreign and domestic markets, outsourced, offshoring, equilibrium wage	Formative: Trading around the world game Summative: Trade Barriers/WTO Summit Formative Sample Question List 3 benefits of specialization. Summative Sample Question Explain why certain goods and services are produced in a particular nation, region, and location. Summative Performance Task Participate in World Trade Organization Summit to restructure trade barriers

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CURRICULUM FRAMEWORK

COURSE: Economics **GRADE:10**

TEACHER'S NAME: **6/17**

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CURRICULUM FRAMEWORK

COURSE: Civics **GRADE:9**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Foundations of Democracy	C1- 9-12a C4- 9-12a	**Concept 1 Comparing Forms of Government** **Essential Questions:** • How should political and economic power be distributed in a society? **Concept 2 The Roots of American Democracy** **Essential Questions:** • What ideas gave birth to the world's first modern democratic nation? • Who were the framers of the Constitution and where did they derive their ideals? • Why did the framers seek a new structure of government and what effect did their past experiences have? • What are the origins of the principles that underlie the American government? **Content Specific Vocabulary** Monarchy, oligarchy, tyranny, democracy, Parliament, authority, sovereignty, coercion, Dictatorship, direct democracy, representative democracy	Formative Political Games Chart Political Games Skit Forms of Government Analysis Chapter 3 and 4 Notes Summative Test 1 Reading Notes Philosophers Philosophers Poster Government Poster Formative Sample Question: Identify the philosophers that influenced American Government and explain how their ideas are evident in the US Government. Summative Performance Task: Create a 3-5 minute skit that demonstrates one or more of the political games that are played behind the scenes in US Government. Summative Question: How and why did the framers distribute power in the Constitution?
		Concept 1 Articles of Confederation	Principles of the Constitution Chart

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CURRICULUM FRAMEWORK

COURSE: Civics **GRADE:9**

The Constitution	C1- 9-12a C2- 6-8b C4- 9-12a	**Essential Questions:** • Why did the weak central government and limited powers of the Articles demonstrate the need for a Constitution? • Why did the framers seek a new structure of government and what effect did their past experience have? Concept 2 Writing of the Constitution **Essential Questions:** • Why was compromise essential to the success of writing the new Constitution? • What was the rationale behind the arguments between the Federalists and Anti-Federalists? • How is "federalism" a compromise between factions in the framers of the Government? Concept 3 The Constitution **Essential Questions** • How is the document structured and organized? • How and why did the framers distribute power in the Constitution?	Constitution Scavenger Hunt Chapter 4 and 5 text Constitution Case Studies Test 2
The Constitution	C1- 9-12a C2- 6-8b C4- 9-12a	**Concept 1 Articles of Confederation** **Essential Questions** • Why did the weak central government and limited powers of the Articles demonstrate the need for a Constitution? • Why did the framers seek a new structure of government and what effect did their past experience have? **Concept 2 Writing of the Constitution**	Formative: Principles of the Constitution Chart Constitution Scavenger Hunt Chapter 4 and 5 text and notes Constitution Case Studies Summative Test 2

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CURRICULUM FRAMEWORK

COURSE: Civics **GRADE:9**

		Essential Questions • Why was compromise essential to the success of writing the new Constitution? **Content Specific Vocabulary** Article of Confederation, Preamble, Amendments, enumerated powers, implied powers, loose construction, strict construction	Formative Sample Question: Create a T-chart comparing the two forms of construction. Summative Sample Question: How did the ruling in Marbury v. Madison create the power of judicial review? Summative Performance Task
The Bill of Rights	C1- 9-12a C2- 6-8b C4- 9-12a	**Concept 1 Bill of Rights** **Essential Questions** • What are the rights guaranteed to all citizens by the Bill of Rights and how do we use them daily? • How have the meanings and the applications of the Bill of rights changed with the changes in American society? **Concept 2 Amendments** **Essential Questions** • Which amendments to the constitution have extended the rights of citizenship by the Bill of Rights to all American citizens? **Content Specific Vocabulary**	Formative: Bill of Rights Scenarios Bill of Rights Case Studies Summative: Know Your Rights Competition Formative Sample Question: Analyze the case of Gideon v. Wainwright and identify the Amendment in question and why. amendment that has been violated and explain why.

COURSE: Civics **GRADE:9**

The Legislative Branch	C3 9-12a	**Concept 1 Lawmakers and Legislators** **Essential Questions** • What makes an effective legislator? • What are the different roles of the Senate and the House? **Concept 2 Congressional Lawmaking** **Essential Questions** • How do laws really get made? **Content Specific Vocabulary** Civil liberties, civil rights, Protection Clause, Incorporation, Establishment Clause, Free Exercise, self-incrimination, double jeopardy,	Formative: Congressional Orientation Chart Chapter reading and questions Lawmaker Wrap Up Summative Bill to a Law Board Game Special Powers Match Up Quiz Formative Sample Question: What are the most important tasks that a legislator has? Summative Sample Question: List the steps from a bill to a law Summative Performance Task
The Executive Branch	C2 6-8b C2 9-12b	**Concept 1 Beyond the President** **Essential Questions** • Who are the people, departments, and agencies that make up the largest branch of the government? **Concept 2 Presidential Powers** **Essential Questions** • What formal and informal powers does the President hold? • What roles and functions does the President perform?	Formative: Formal and Informal Powers of the President Chart and Activity Executive Departments Notes Summative Exec. Dept.Research Projects Test Formative Sample Question: Which part of the Constitution grants the president flexible powers? Summative Sample Question: What must take place in order to

		Content Specific Vocabulary Succession, impeachment, incumbent, amnesty, elastic clause, veto, inauguration	impeach a President?
			Impeach a President Summative Performance Task Present Executive Department Projects
The Judicial Branch	C2 9-12b	**Concept 1 Courts, Judges, and the Law** **Essential Questions** • How is the US Judicial system organized to ensure justice? • How does the Constitution guarantee due process? **Concept 2 Checks and Balances** **Essential Questions** • How do the three branches at work display the system of checks and balances? **Content Specific Vocabulary** Burden of proof, preponderance of evidence, plaintiff, appellate court, jurisdiction, majority opinion, dissenting opinion	Formative: Chapter reading, notes, and questions Court review Summative: Analyzing Court Materials Federal and State Summary Chart SC case studies Test Formative Sample Question In a civil case, what must the plaintiff prove? Summative Sample Question How is the judicial branch involved in the system of checks and balances? Summative Performance Task Role Play of Supreme Court 1st and 4th Amendment cases
Elections	C3 9-12a	**Concept 1 Political Campaigns** **Essential Questions** • What processes are in place for electing a candidate to office?	Formative: Electoral College Activity Summative:

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CURRICULUM FRAMEWORK

COURSE: Civics **GRADE:9**

		Concept 2 Presidential Election **Essential Questions** • What is the role of the Electoral College? **Content Specific Vocabulary** Winner-take-all, caucus, primary, Electoral College, Convention	Issues Research Issues Paper Issues Presentation Formative Sample Question Identify ways a citizen can participate in the political process. Summative Sample Question How is it possible to win a presidential election without winning the popular vote?
			Summative Performance Task Teach selected campaign issue to middle school students

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CURRICULUM FRAMEWORK

COURSE: Civics **GRADE:9**

TEACHER'S NAME: **Desmond** **6/17**

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CURRICULUM FRAMEWORK

COURSE: Health **GRADE: 9**

Unit	Standards	Unit Concept /Essential Questions	Assessments
Physical Health	**DE Health Standards** 1.1 1.4 1.5 1.7 1.8 2.1 2.8 3.4 5.3 5.5 5.6 6.1 7.2 8.2 8.4 **Focus:** Digestive System Nutrition Cardiovascular System Nervous System Skeletal System	**Unit 1 – Physical Health -Essential Questions** • What is health? • How do food choices help to support a healthy life style? • How do your choices relate to the functioning of your body systems? • How do the structure and functions of our body systems allow us to meet our physical needs? • How does the use of alcohol and drugs affect our body systems? **Content Specific Vocabulary** epiglottis, stomach, small intestine, colon, digestion, peristalsis, bile, gallbladder, nutrient, metabolism, calorie, carbohydrate, fiber, fat, unsaturated fat, saturated fat, cholesterol, trans fat, protein, amino acid, joint, cartilage, ossification ,marrow, ligament, osteoporosis, fracture, sprain, dislocation, scoliosis, smooth muscle, cardiac muscle, skeletal muscle, neuron, cerebrum, cerebellum, brain stem, spinal cord, atrium, ventricle, artery, capillary, vein, blood pressure, plasma, red blood cell, white blood cell, platelet, atherosclerosis, arrhythmia, pituitary gland, puberty, sperm, fertilization, testes, testosterone, scrotum, penis, semen, infertility, ova, ovaries, estrogen, progesterone, ovulation, fallopian tubes, uterus, vagina, sexually transmitted infection, depressant, intoxication, blood alcohol concentration (BAC), overdose, binge drinking, barbiturates, opiate, amphetamines **Text** Pruitt, B E., John P. Allegrante, and Deborah Prothrow-Stith. *Health*. Boston, Pearson, 2014. Journal articles as related to the topic	Lesson Quizzes - Formative Unit Test - Summative Digestive System Story – Summative Students write a first person narrative from the perspective of a chocolate chip cookie on its passage through the digestive system. Correct anatomical descriptions are required. Meal Planning – Formative Students record their daily food intake and then assess how they met basic nutrition needs based on their diet. Recommendations for changes to eating habits in order to maintain a healthier life style are required. Digestive System Model – Formative Students work together to create a human model of the digestive system. STD Brochure – Formative Students design a brochure to be handed out to fellow students discussing important information regarding a specific

	Reproductive System Sexually Transmitted Diseases Alcohol and Drug Use		sexually transmitted disease. Heart Rate Lab – Formative Students perform a lab in which they monitor their heart rate and determine what effect exercise has on heart rate. PSA Drug and Alcohol Use Video – Formative Students write, direct, and perform a public service announcement that warns teens of the affects of alcohol and drugs on the body.
Emotional and Mental Health	**DE Health Standards** 1.1 1.3 1.4 1.5 2.1 2.3 2.4 2.5 2.7 3.1 3.4 5.1 5.3	**Unit 2: Mental and Emotional Health - Essential Questions** • What influences my mental and emotional health? • What does it mean to be mentally and emotionally healthy? • How does stress influence health? • How do mental health disorders affect students and communities? **Content Specific Vocabulary** heredity, risk factor, prevention, personality, peer group, identity, self-esteem, self-actualization, hierarchy of needs, primary emotion, learned emotion, coping strategy, defense mechanism, stress, eustress, distress, stressor, optimism, pessimism, perfectionist, resilience, mental disorder, anxiety, anxiety disorder, phobia, obsession, compulsion, mood disorder, depression, schizophrenia, personality disorder, eating disorder, anorexia nervosa, bulimia, binge eating disorder, clinical depression, cutting, suicide, cluster suicide	Lesson Quizzes – Formative Unit Test – Summative Stress Infographic – Summative Students create an infographic to represent information learned about both good and bad stress, its effects on the body, and ways to positively manage stress. Personality Development Timeline – Formative Students create a timeline of personality development, which includes major

	5.5 6.3 7.1 7.3 8.2 8.4 Focus: Self-esteem Stress management Personal health Mental illness Suicide prevention	**Text** Pruitt, B E., John P. Allegrante, and Deborah Prothrow-Stith. *Health*. Boston, Pearson, 2014. Journal articles as related to the topics	milestones within each stage. The status of self-esteem during each stage will also be indicated. Self Esteem Role Play – Formative Students role-play hypothetical situations that occurs in the lives of teenagers and reflect on the effect of these situations on the self-esteem of all involved. Stressed and Depressed Letter – Summative Students will write a letter to a "stressed and depressed" student addressing his/her depression and what might help them feel better and also outlines coping strategies that can be employed. Stigma Elimination Presentation – Formative Students research a form of mental illness and then present the myths and truths to their classmates with the goal of educating and eliminating the stigma that surrounds mental illness.
Social Health	**DE Health Standards** 1.2	**Unit 3: Social Health – Essential Questions** • What barriers exist to hinder healthy decision making? • How do the influences of peer groups, family, and culture affect decision making?	Unit Test – Summative Lesson Quizzes - Formative

	1.7 2.1 2.2 2.3 2.5 4.1 4.2 4.3 4.4 5.2 5.5 5.6 8.1 8.2 **Focus:** Assertive Communication Conflict Resolution Peer Pressure	• How does effective communication influence health? **Content Specific Vocabulary** Empathy, communication, active listening, passive, aggressive, assertive, body language, eye contact, cooperation, compromise, infatuation, dating violence, date rape **Text:** Pruitt, B E., John P. Allegrante, and Deborah Prothrow-Stith. *Health*. Boston, Pearson, 2014. Journal articles as related to the topics	Peer Pressure Performance – Formative Students are given scenarios where they need to identify the role of peer pressure and then w role-play effective assertive communication to deal with the peer pressure. Active Listening/Conflict Resolution – Performance Task Students will be asked to participate in a role- play where conflict arises and they will need to use active listening and conflict resolution skills that they have learned in class to come to a resolution.

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors Biology **GRADE 10**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1- Biology Basics	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-2 HS-LS1-6	Essential Question: • How does the nature of science, scientific method, chemistry of life, properties of water, and macromolecules serve as a foundation for what we learn about biology throughout the year? Learning Objectives *Student will be able to…* - Define science. - Give an example of a hypothesis in the correct format. - Explain the relationship between independent and dependent variables within a hypothesis. - Explain the difference between an observation and an inference. - Explain the difference between accuracy and precision. - List the components of the scientific method. - Give an example of a scientific investigation design, with appropriate constants and variables (IV and DV) - Be able to conduct a scientific experiment. - Be able to organize data from an experiment in a chart, table, or graph and interpret it. - Analyze data with respect to a hypothesis and draw an appropriate conclusion. - Be able to select the most appropriate hypothesis given the description of a scientific investigation. - Identify constants and variables given a description of a scientific investigation. - List the stages of the technological design process. - List the criteria that must be considered during the solution design stage of the technological design process. - Compare and contrast the scientific investigation with the technological design process. - List the monomers and polymers of carbohydrates, lipids, proteins, and nucleic acids.	The following assessments will provide evidence of student learning: Formative: Classwork/Labs: - Daily Vocab Slam Quizzes – via Schoology - Lab Stations: Safety and Equipment - Lab Stations: Measurement - Practice: Understanding Hypotheses - Practice: Scientific Method - Lab: An Investigation of Sanitizers and Soaps - Lab: The Water Tower Challenge - Lab: Murder and a Meal - Lab: Macromolecule Diet and Exercise Online Simulation Homework: - Concepts 1-3 Study Guides Summative:

TEACHER'S NAME: Jennifer Couch **6/17**

		- Explain the major functions of each macromolecule. - Provide an example for each type of macromolecule. - Compare the relative energy storage of carbohydrates, lipids, and proteins. - List the order in which the body will consume carbohydrates, lipids, and proteins for energy, and explain why. Content Specific Vocabulary: Qualitative, precision, observation, quantitative, accuracy, inference, independent variable, dependent variable, constants/controlled variables, experimental group, control group,Matter, atom, element, isotopes, compound, molecule, cation, anion,Macromolecules	Tests: - Unit 1: Concepts 1-3 Projects/Reports/ Performance Tasks: - Hand Sanitizer/Soap Lab Formal Lab Report – CSET Rubric
Unit 2- Cells	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-2 HS-LS1-4	Essential Question: • How do cells and the organelles within them work together to form the basis of all life? Learning Objectives: *Students will be able to…* - List the 3 principles of cell theory. - Explain the difference between multicellular and unicellular organisms. - Compare and contrast prokaryotic and eukaryotic cells. - Compare and contrast plant and animal cells. - Describe the function of the following organelles: Nucleus, Mitochondria, Vesicles, Lysosome, Chloroplast, Vacuoles, Ribosomes, Cilia, Flagella, Cell membrane (phospholipid bilayer), Cell wall, Cytoplasm, Golgi apparatus, Endoplasmic reticulum (Rough and Smooth), Centrioles (Centrosomes). - Identify an organelle based on a diagram or description. - Identify a cell as eukaryotic, prokaryotic, plant, or animal based on a description or diagram. - Predict the consequences of the failure or absence of an organelle inside a eukaryotic cell. - Define homeostasis and explain the importance of it.	The following assessments will provide evidence of student learning: Formative: Classwork/Labs: • Daily Vocab Slam Quizzes- via Schoology • Practice: Organelle Identification • Practice: Labeling the Cell • Practice: Cell Analogy • Practice: Types of Cellular Transport • Lab: Exploring Osmosis

		- Explain the structure of the cell membrane and how its structure allows it to control what goes in and out of the cell. - Create a Venn Diagram to compare and contrast passive and active transport. - Describe the six types of transport. Include examples of the substances moved in each. - Explain the differences between hypotonic, isotonic, and hypertonic solutions. You may use a picture to help you describe. - Explain the difference between phagocytosis and pinocytosis. - Classify a type of cellular transport as active or passive based on a diagram or description. - Infer which type of cell transport would be best suited to move a given substance across the cell membrane. - Classify solutions as hypertonic, hypotonic or isotonic based on a diagram or description. - List and define each of the five levels of organization. - Explain the difference between differentiated/specialized cells and stem cells. - Summarize the importance of stem cells and the differences between adult and embryonic. - List the two main purposes for cell division. - Describe ALL PHASES of the cell cycle, as well as the stages of mitosis in order. - Explain how cells know when they need to divide. Also, explain the difference between internal and external regulation. - Define cancer, causes of cancer, and the types of tumors that may result. - Identify what stage of mitosis a cell is in based on a description or diagram. - Predict consequences of a failure during a given phase of the cell cycle or mitosis. Content Specific Vocabulary: • Eukaryote, Prokaryote, Organelle • Homeostasis, Passive transport, Diffusion, Osmosis, Hypertonic, Hypotonic, Isotonic, Facilitated diffusion, Active transport, Molecular pumps, Endocytosis, Exocytosis • Differentiation, Daughter cells, Sister chromatids, Centrioles, Spindle fibers, Cell cycle,	• Practice: Putting it All Together • Research: A Look at Stem Cells • Practice: Cell Cycle • Activity: Mitosis Flipbooks • Lab Stations: A Closer Look at Cancer Homework: • Concepts 1-3 Study Guides Summative: Tests/Quizzes: • Organelle Quiz • Unit 2: Concepts 1-3 + Cumulative Projects/Reports/ Performance Tasks: • Cell Organelle Project • Exploring Osmosis Lab Formal Lab Report – CSET Rubric

		Interphase, Mitosis, Prophase, Metaphase, Anaphase, Telophase, Cytokinesis, Cleavage furrow/ Cell plate, Cancer, Carcinogen, Malignant, Benign	
Unit 3- Energy Flow	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-5 HS-LS1-6 HS-LS1-7 HS-LS2-3 HS-LS2-4 HS-LS2-5	Essential Question: • How do living things obtain and use energy? Learning Objectives: *Students will be able to…* - Explain the function of enzymes in biochemical reactions, such as photosynthesis and cellular respiration. - Draw and label energy diagrams of biochemical reactions (endothermic AND exothermic), including products, reactants, and activation energy. - Describe the five factors that affect the rate of chemical reactions. - Draw and label the lock-and-key model, including enzyme, substrate, active site, and product. - Explain the purpose of a molecule of ATP and where most of the energy is stored in the molecule. - Draw the structure and label the parts of a molecule of ATP. - Describe the ATP-ADP cycle. Include what is and is not recycled. - Explain what the energy is used for when a phosphate is removed, and where that energy initially comes from. - Describe why the pyramid shape is used to represent energy, biomass, and numbers pyramids. - Draw an example of an energy pyramid and explain how energy flows through each level. Label the trophic level, classify the type of organism and give an example of an organism at each level. - Explain the difference between how autotrophs and heterotrophs acquire energy. - Explain the significance of detrivores (decomposers) in a food chain/food web. - Use a Venn Diagram to compare and contrast photosynthesis and chemosynthesis. - Interpret a food chain or food web.	The following assessments will provide evidence of student learning: Formative: Classwork/Labs: - Daily Vocab Slam Quizzes via Schoology - Lab: Simulating a Chemical Reaction - Practice: Putting it All Together (Enzymes) - Activity: Making an ATP Model - Practice: Putting it All Together (ATP) - Practice: Energy Flow #1 - Practice: Energy Flow #2 - Lab Stations: Build a Food Web - Practice: Photosynthesis Visual Summary - Practice: Photosynthesis Concept Map - Activity: Photosynthesis Relay - Practice: Photosynthesis and Cellular Respiration Comparison

		- Calculate the energy, number of organisms, or biomass lost between trophic levels. - Identify a trophic level based on a description or diagram. - Classify an organism depending on what type of consumer it is based on a description or diagram. - Classify an organism as an autotroph or heterotroph based on a description or picture. - Explain where all energy on Earth comes from and the overall processes it goes through to be in a usable form of ATP for consumers like us. - Write and interpret the chemical formula for photosynthesis. Label the reactants and products. - Explain why plants are green. - Describe the significant events of the light-dependent and light-independent reactions. Include which reactants and products are a part of each stage. Highlight what will be released as a product and what will move on to the next stage. Be sure to include locations. - Explain the alternative pathways some plants, like cacti and corn, will take to get energy. - Describe the three factors that affect the rate of photosynthesis. - Explain the overall goal of cellular respiration. - Write and interpret the chemical formula for cellular respiration. Label the reactants and products. - Describe the difference between aerobic and anaerobic respiration. Include the difference in overall ATP production. - Describe the significant events of aerobic respiration (Krebs Cycle and ETC) AND anaerobic respiration (fermentation). Be sure to start each process with glycolysis. Include which reactants and products (if any) are a part of each stage. Be sure to explain where each process occurs in the cell. - Describe the two types of anaerobic respiration. Include what is used, what is made, and examples of organisms that do each process. Content Specific Vocabulary: • Chemical reactions, Activation energy, Reactants, Products, Endothermic, Exothermic,	- Practice: Cellular Respiration Visual Summary - Practice: Cellular Respiration Concept Map - Activity: Journey of a Photon - Practice: Vocabulary Review - Practice: Biochemical Reactions Summary - Practice: Putting it All Together (Energy Flow) Homework: - Concepts 1-5 Study Guides Summative: Tests/Quizzes: - Unit 3: Concepts 1-2 + Cumulative - Unit 3: Concepts 3-5 + Cumulative Projects/Reports/ Performance Tasks: Simulating a Chemical Reaction Lab Formal Lab Report – CSET Rubric

		Active site, Denature • ATP, Chemiosmosis • Autotroph, Heterotroph, Detrivore, Carnivore, Omnivore, Herbivore, Chemosynthesis • Photosynthesis, Grana, Stroma, Photosystems, Electron carriers, Stomata, Photorespiration • Inner Membrane, Matrix, Aerobic, Anaerobic	
Unit 4- Genetics	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-4 HS-LS1-6 HS-LS3-1 HS-LS3-2	Essential Question: • How is genetic information from a living organism passed on to its offspring? Learning Objectives: *Student will be able to:* - Use a Venn diagram to compare and contrast DNA and RNA. - Explain the base pairing rules of DNA. Provide an example of a strand of DNA with its complementary pair. - Draw the structure of a nucleotide and label the parts. - Describe the difference between purines and pyrimidines and list which nitrogen bases are which. - Explain, in detail, the structure of a DNA molecule. - Explain the differences between a strand of DNA, genes, and a chromosome. - Summarize the process of DNA replication. - Describe the difference between the leading strand and the lagging strand in DNA replication. - Explain the function of each enzyme in the process of DNA replication. - *Identify a nucleic acid as DNA or RNA based on a description or diagram.* - Describe the relationship between genes and proteins. - Explain the central dogma. - Describe the roles of the three types of RNA in protein synthesis. Draw a sketch of what each type looks like. - Summarize, in detail, the steps in transcription and translation. Include location of process and	The following assessments will provide evidence of student learning: Formative: Classwork/Labs: - Daily Vocab Slam Quizzes- via Schoology - Video Questions: Cracking the Code of Life - Activity: Understanding DNA Structure - Practice: DNA Structure and Replication - Practice: Transcribing and Translating - Activity: Building a Candy Model - Practice: Protein Synthesis - Activity: Protein Synthesis Scavenger Hunt OR Protein Synthesis Relay Game - Game: Protein Syn-thingo - Practice: Haploid v. Diploid

		enzymes involved. - Transcribe the following strand of DNA to mRNA, and translate a sequence of amino acids from the mRNA: TACACCGGAGCGTTTATT - Explain what would happen if a mistake is made during protein synthesis. - Describe the difference between haploid cells and diploid cells. - Explain the significance of crossing over during prophase I/metaphase I. - Describe the difference between somatic cells and sex cells. - Describe the difference between autosomes and sex chromosomes. - Explain the purpose and results of meiosis compared to mitosis. - Explain what would happen if a mistake is made during meiosis. - *Identify a cell as haploid or diploid based on a description or picture.* Content Specific Vocabulary: • Nucleic acid, Nucleotide, Chromosome, Gene, DNA, Leading strand, Lagging strand, RNA, RNA primer, Okazaki fragments, Semi-Conservative • Transcription, Translation, mRNA, tRNA, rRNA, Codon, Gene, Amino acid • Karyotype, Crossing-over, Somatic cell, Gamete, Autosome, Sex chromosome, Diploid, Haploid	- Practice: Meiosis - Lab Stations: Putting it All Together Homework: - Concepts 1-3 Study Guides Summative: Tests/Quizzes: - Unit 4: Concepts 1-3 Projects/Reports/ Performance Tasks: - DNA model – DNA project rubric
Unit 5- Heredity	*Next Generation Science Standards by NSTA and Delaware Department of Education:*	Essential Question: • How is genetic information expressed in order to make us who we are? Learning Objectives: *Student will be able to:* - Explain Mendel's three laws of inheritance. - Create an example of a monohybrid cross and a dihybrid cross using Punnett squares. - Define and give examples of homozygous, heterozygous, dominant, and recessive.	The following assessments will provide evidence of student learning: Formative: Classwork/Labs: - Daily Vocab Slam Quizzes via Schoology - Practice: Monohybrid Crosses

	HS-LS3-1 HS-LS3-2 HS-LS3-3	- *Given parental phenotypes or genotypes, identify all possible gametes that could be produced using a Punnett squares. Determine genotypic and phenotypic ratios from your results.* - *Be able to use the rules of probability to determine likelihood of inheriting different combinations of alleles.* - Describe the difference between incomplete dominance and co-dominance. Give examples of each. - Explain the difference between multiple alleles and polygenic traits. Give examples of each. - Explain how blood type is an example of both co-dominance and multiple alleles. - Explain the difference between linked genes and sex-linked traits. Give examples of each. - Explain the difference between traits inherited on sex chromosomes and traits inherited on autosomes. - *Be able to perform crosses, using Punnett squares, for complex inheritance patterns.* - *Identify a type of inheritance pattern based on a description*. - Describe the basic definition of a mutation, as well as some causes of mutation. - Explain the difference between mutations in sex cells and those in somatic cells. - Explain the difference between gene and chromosomal mutations. Give an example of disorders caused by each. - Explain the different types of gene mutations and chromosome mutations. - *Identify a type of mutation based on a description or a picture.* - *Use a pedigree to determine if a trait is dominant or recessive, and sex-linked or autosomal.* - List and explain the types of genetic engineering discussed in class. - Describe the significance of genetic engineering to science, technology, and society – both positively and negatively. - *Be able to identify a suspect using gel electrophoresis* Content Specific Vocabulary: • Genotype, Phenotype, Alleles, Genes, Heterozygous, Homozygous, Dominant, Recessive, Homologous chromosomes	- Practice: Dihybrid Crosses - Practice: Punnett Squares - Activity: Popsicle Stick Babies - Practice: Heredity Vocabulary - Lab Stations Activity: Investigating Complex Inheritance Patterns - Practice: Complex Inheritance Word Problems - Practice: Pedigrees - Lab Activity: Blood Type Pedigree Mystery - Video Questions: Pre- and Post-GATTACA Homework: - Concepts 1-4 Study Guides Summative: Tests/Quizzes: - Punnett Square Quiz - Complex Inheritance Patterns Quiz - Unit 5: Concepts 1-4 + Cumulative Projects/Reports/ Performance Tasks:

		• Epistasis, Autosomes, Sex chromosomes, Incomplete dominance, Co-dominance, Polygenic inheritance, Linked genes, Sex-linked traits • Mutation, Mutagen, Somatic cells, Gametes, Nondisjunction, Carrier, Pedigree, Gene mutation, Chromosomal mutation • Genetic engineering, Human Genome Project, Gel electrophoresis, Plasmid, Recombinant DNA technology, CRISPR	- Genetic Disorder Research Project
Unit 6-Evolution	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS3-2 HS-LS4-1 HS-LS4-2 HS-LS4-3 HS-LS4-4 HS-LS4-5	Essential Question: How to species change over time to survive in different environmental conditions? Learning Objectives: *Student will be able to:* - List the different scientists and their discoveries that led up to Darwin and his theory of natural selection. - Summarize what Darwin concluded after his journey on the Beagle. - Explain the four main principles of natural selection. Give a real world example of evolution and how it fulfills each principle. - Explain the difference between the three modes of selection. Sketch pictures and provide a real-world example of each. - Explain how diversity within a species has resulted in an increase in fitness (survival of the fittest). - Describe the factors that influence genetic variation. - List the 5 factors that must be true for evolution to not occur. - Explain the difference between finding the genotypic frequency versus the allele frequency. - Explain how you approach a practice problem differently if the population is in HWE or it isn't. - *Be able to perform calculations of allele and genotype frequencies.* - Describe the patterns of evolution, in detail. - Explain the difference between a gradual extinction and a mass extinction.	The following assessments will provide evidence of student learning: Formative: Classwork/Labs: - Daily Vocab Slam Quizzes- via Schoology - Practice: Principles of Natural Selection - Lab: Natural Selection - Practice: Modes of Selection - Practice: HWE #1 - Practice: HWE #2 - Video Questions: The Evolutionary Arms Race - Practice: Patterns of Evolution - Lab Stations Activity: Exploring Evolution - Practice: Evolution Vocabulary - Practice: Phylogenetic Trees #1 - Practice: Phylogenetic Trees #2

		- Who is better at evolving – sexual or asexual reproducers? Explain. - List and describe the fields of study that provide evidence for the theory of evolution. - Explain the differences between homologous, analogous, and vestigial structures. Be sure to indicate which pattern of evolution leads to these structures, as well as an example of each. - List the two macromolecules that provide evidence for evolution in the field of biochemistry. - *Describe relationships between organisms based on evidence gathered in various fields of study within biological evolution.* - Explain what phylogenetic trees represent and what we use them for. - List the levels of classification recognized by modern taxonomists and how they relate to phylogenetic trees. - Explain what binomial nomenclature is and who came up with it. - *Interpret a phylogenetic tree in order to make statements about relationships between organisms.* Content Specific Vocabulary: • Natural selection, Biological evolution, Microevolution, Macroevolution, Fitness, Gene pool, Genetic drift, Gene flow, Sexual selection, Genetic equilibrium, Hardy-Weinberg principle • Gradualism, Punctuated equilibrium, Adaptive radiation, Divergent evolution, convergent evolution, Co-evolution, Extinction, (gradual and mass), Sexual and asexual reproduction • Biogeography, Anatomy, Homologous structures, Analogous structures, Embryology, Biochemistry, Paleontology, Fossils, Transitional fossils • Taxonomy, Phylogeny, Phylogenetic tree	- Practice: Putting it All Together Homework: - Concepts 1-4 Study Guides Summative: Tests/Quizzes: - Unit 6: Concepts 1-4 + Cumulative Projects/Reports/ Performance Tasks: - Adaption Lab Formal Report – CSET Rubric
Unit 7- Ecology	*Next Generation Science Standards by*	Essential Question: • How do the living and nonliving components of an ecosystem relate to each other?	*The following assessments will provide evidence of student learning:*

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors Biology **GRADE 10**

	NSTA and Delaware Department of Education: HS-LS2-1 HS-LS2-2 HS-LS2-3 HS-LS2-4 HS-LS2-5 HS-LS2-6 HS-LS2-7 HS-LS2-8 HS-LS4-6	Learning Objectives: *Student will be able to:* - List the characteristics an organism must possess in order to be considered living. - Explain the difference between sexual and asexual reproduction. - List the levels of organization recognized by ecology. - List the levels of classification of organisms recognized by taxonomy. - *Interpret a cladogram in order to make statements about relationships between organisms.* - *Classify organisms when given a dichotomous key.* - Describe specific stages in *each* geochemical cycle. - List where living organisms (both human and non-human) play a role in each geochemical cycle. - *Given a diagram of any geochemical cycle, be able to label the stages illustrated.* - *Given specific stages, be able to state which geochemical cycle(s) they may belong to.* - Explain the difference between logistic and exponential population growth. - Cite specific examples of each type of limiting factor. - Explain what a stable ecosystem is. - Describe the three types of survivorship curves. - *Classify limiting factors as density-dependent, density-independent, biotic, or abiotic.* - *Explain the difference between immigration and emigration.* - *Infer how a population's growth would be affected by a change in the availability (increase or decrease) of any limiting factor.* - *Calculate a population's density.* - *Interpret a graph that shows how a population's size has changed over time.* - Explain the influence humans have on the three geochemical cycles. - Explain the difference between renewable and nonrenewable resources, and state examples of each. - Describe the three types of technology humans use and the pros and cons of each. - *Interpret a graph that displays information about how humans have influenced the environment (ozone layer, atmosphere, etc…)*	Formative: Classwork/Labs: - Daily Vocab Slam Quizzes via Schoology - Activity: Biome Research Advertisement - Practice: Classification using Dichotomous Keys - Activity: Candy Dichotomous Keys - Activity: Water Cycle - Activity: Carbon Cycle Cartoon - Activity: Nitrogen Cycle - Practice: Geochemical Cycles - Investigation: Ecosystem in a Bottle in Class Project - Activity: Stop the Spread! - Practice: Population Ecology - Lab Stations: Exploring Ecological Succession - Lab Activity: Predation - Practice: Interactions of Organisms Homework: - Concepts 1-6 Study Guides

TEACHER'S NAME: Jennifer Couch **6/17**

		- Explain the process of ecological succession and what kinds of conditions give rise to primary vs. secondary succession. - Explain how humans impact the process of ecological succession. - Describe the role of pioneer species in beginning the process of primary ecological succession, as well as a climax community at the end of both primary and secondary succession. - *Identify a type of succession as primary or secondary based on an illustration or description.* - Explain how the relationship between predators and prey generates stability over time. - Explain how both organisms are affected in each type of ecological relationship and list specific examples of each type of ecological relationship. - *Classify a relationship as predation, competition, or symbiosis based on a description or pictures.* - *Classify an organism as predator, prey, host, or parasite based on a description or pictures.* - *Classify a symbiotic relationship as mutualistic, commensalistic, or parasitic based on a description or pictures of organisms involved.* Content Specific Vocabulary: • Ecology, Organism, Population, Community, Ecosystem, Biome, Biosphere, Biodiversity • Geochemical cycles • Exponential growth, Logistic growth, Population, Carrying capacity, Limiting factors, Density-dependent, Density- independent, Abiotic, Biotic, Immigration, Emigration, Stable ecosystem • Sustainability, Ecological/carbon footprint, Global warming/Greenhouse effect, Resources, Renewable, Nonrenewable • Ecological succession, Primary succession, Secondary succession, Pioneer species, Climax community, Niche, Habitat, Predator, Prey, Competition, Interspecific, Intraspecific, Competitive exclusion, Symbiosis, Parasitism, Mutualism, Commensalism	Summative: Tests/Quizzes: - Geochemical Cycles Quiz - Unit 7 Test: Concepts 1-3 + Cumulative - Unit 7 Test: Concepts 4-6 + Cumulative Projects/Reports/ Performance Tasks: - Microbial Fuel Cell Project

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Integrated Science **GRADE: 9**

Unit	Standards	Unit Concept /Essential Questions	Assessments
Forces and Interactions	HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-5 Focus: Newton's Laws Momentum Force Electro-magnetism Waves and Motion	Unit 1 – Forces and Interactions • How are force, motion, and momentum connected? • How can one explain and predict interactions between objects and within systems of objects? • How is energy transferred and conserved? • How are waves used to transfer energy and send and store information? Content Specific Vocabulary frame of reference, relative motion, distance, vector, resultant vector, speed, average speed, velocity, acceleration, constant acceleration, linear graph, force, Newton, net force, friction, static friction, rolling friction, sliding friction, fluid friction, air resistance, gravity, terminal velocity, projectile motion, inertia, mass, weight, momentum, law of conservation of momentum Text Wysession, Michael, David Frank, and Sophia Yancopoulos. *Physical Science Concepts in Action*. Boston, Pearson, 2011. Journal Articles as related to the topics	Lesson Quizzes - Formative Unit Test - Summative Friction Inquiry Lab – Performance Task Students design and execute a lab to test the effect of friction on objects of their choosing. Calculations and data analysis required. Video Tutorial – Performance Task Students create video tutorial explaining physics concepts covered in class to help struggling students. Speed and Velocity Challenge – Summative Students are challenged to make a tennis ball move with a specified velocity. They must prove this using mathematical calculations Collision Carts Simulation- Formative Students perform simulations and analyze resulting data to draw conclusions. Roller Coaster Design Project- Summative Students use calculations of KE and PE to design a roller coaster that is safe and fun for people to ride. Egg Drop – Performance Task Students design a contraption to protect an

			egg from external forces. Calculations, data collection, and conclusion are included in final lab write-up. Sample Summative Assessment Question: Your goal is to make a tennis ball have an average velocity of 2.4 m/s going down a ramp. Once you let go of the ball, you may not touch it again as the ball is rolling. Gravity is the only force allowed to move the ball down the ramp. Your final answer needs to show at least 5 successful completions of your task. You must prove mathematically that your ball was traveling exactly 2.4 m/s.
Matter and Chemistry	HS-PS1-1 HS-PS2-6 HS-PS1-2 HS-PS1-5 HS-PS1-7 HS-PS3-4 Focus: Properties of Matter States of Matter Atomic Structure Energy Transfer Chemical Bonds Periodic Table Chemical	Unit 2 – Matter and Chemistry • How can one explain the structure and properties of matter? • How do substances combine or change to make new substances? • How does one characterize and explain these reactions and make predictions about them? • How does energy transfer occur through chemical reactions? Content Specific Vocabulary pure substance, element, atom, compound, heterogeneous mixture, homogenous mixture, solution, suspension, colloid, chemical property, flammability, reactivity, chemical change, precipitate, solid, liquid, gas, kinetic energy, pressure, absolute zero, Charles Law, Boyle's Law, endothermic, exothermic, vaporization, sublimation, deposition, nucleus, proton, electron, neutron, atomic number, mass number, isotopes, energy levels, electron cloud, orbital, electron configuration, ground state, periodic table, period, group, atomic mass unit, metals, transition metals, non-metals, metalloids, valence electron, alkali metals, alkaline earth metals, halogens, noble gases, ion, anion, cation, chemical bond, ionic bond, chemical formula	Lesson Quizzes – Formative Unit Test - Summative Chemical vs. Physical Properties Lab – Formative Students make observations of experiments to draw conclusions regarding whether a physical change or a chemical change occurred. States of Matter Model – Formative Students create a model that depicts each state of matter at a molecular level. Gas Laws Experiments – Formative

	Reactions	Text Wysession, Michael, David Frank, and Sophia Yancopoulos. *Physical Science Concepts in Action*. Boston, Pearson, 2011. Journal Articles as related to the topics	Students rotate through stations and perform small experiments and draw conclusions about gas laws. Interview – Performance Task Students write and perform a mock interview with a scientist who contributed significantly to atomic theory. Chemical Bonding Go Fish – Formative Students demonstrate their knowledge of ionic and covalent bonding through the creation of compounds. Endo v. Exothermic Reactions Lab – Formative Students perform a lab that demonstrates conservation of energy and submit a written lab report that includes data analysis and a conclusion of findings.
Earth Science	HS-ESS1-2 HS-ESS1-3 HS-ESS1-5 HS-ESS1-6 HS-ESS2-1 HS-ESS2-2 HS-ESS2-3 HS-ESS2-4 HS-ESS2-5	Unit 3 – Earth Science • How do people reconstruct and date events in Earth's Planetary history? • How do we know the Big Bang happened? • How are stars connected to the production of elements? • How do plate tectonics help us to understand continental and oceanic features? • How do waves travel through different mediums and what can they tell us? • How does energy relate to climate and climate change? • How does climate change impact earth's systems?	Lesson Quizzes – Formative Unit Test – Summative Autobiography of a Star – Formative Students take on the persona of a star and write their autobiography Model of Plate Tectonics – Formative

	HS-ESS2-6 HS-ESS3-5 Focus: Big Bang Theory Plate Tectonics Geologic Time Feedback Loops Climate Science Carbon Cycle	Content Specific Vocabulary crust, mantle, lithosphere, asthenosphere, mesosphere, core, plate tectonics, Pangaea, continental drift, mid-ocean ridge, sea-floor spreading, subduction, trench, divergent boundary, convergent boundary, transform boundary, earthquake, seismic waves, tsunami, stress, fault, fold, focus, epicenter, P waves, S waves, surface waves, seismograph, volcanoes, ground water, water cycle, transpiration, tributaries, watershed, water table, aquifer, erosion, weathering, deposition, flood plain, alluvial fan, delta, climate, El Nino, global warming, greenhouse effect, carbon cycle, respiration, photosynthesis, solar nebula, protoplanetary disk, red shift, nebula, protostar, Hubble's Law, big bang theory, cosmic microwave background radiation Text Wysession, Michael, David Frank, and Sophia Yancopoulos. *Physical Science Concepts in Action*. Boston, Pearson, 2011. Journal Articles as related to the topics	Students create a model of various types of plate boundaries and use these to explain geologic time Climate Change Debate – Performance Task Students debate the role humans play in climate change and make predictions about the impact of global climate change Job Descriptions – Summative Students will write a job description for a water droplet that explain properties of water and the effects that it can have on the earth's surface Earthquakes and Seismic Waves Lab – Formative Students use seismic wave data to calculate the location of the epicenter and focus of an earthquake. Lesson Creation – Summative Students will create and perform a lesson for their classmates on one of the following topics: the life of a star, plate tectonics, seismic waves, water shapes the land, carbon cycling, climate change

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Integrated Science **GRADE: 9**

TEACHER'S NAME: Stephanie Sherman **6/17**

Delaware Department of Education
CTE & STEM Office
401 Federal Street, Suite 256
Dover, DE 19901
PHONE: 302.735.4015 FAX: 302.739.1780

DELAWARE CTE MIDDLE SCHOOL APPLICATION

LOCAL EDUCATION AGENCY INFORMATION		
Local Education Agency (LEA): **Sussex Academy**		
School(s) where the Course will be Located: **Sussex Academy**		**Start Date:** August 2017
LEA CTE Coordinator Name: **Allen Stafford**	**Phone:** **302-856-3636**	**E-Mail Address:** **allen.stafford@saas.k12.de.us**
Course Title: STEM in Computer Science I **Grade Level:** 7 **Course Title:** STEM in Computer Science II **Grade Level:** 8		
CTE Program(s) of Study Alignment: **High School:** Sussex Academy **Program(s) of Study:** PLTW Engineering and Computer Science Principles (value added course)		

ASSURANCES & SIGNATURES	
CTE Program of Study approval and funding is contingent upon the following assurances: 1. The LEA will comply with Delaware Administrative Code, 14 Del.C. §525, Requirements for Career and Technical Education Programs and the Delaware State Plan for the Carl D. Perkins Career and Technical Education Act of 2006; 2. The LEA will submit CTE program data as required by the Delaware Department of Education; 3. All teachers are certified in the appropriate CTE area and participate in program specific professional learning; 4. The LEA will convene and engage a program advisory committee for the purposes of program development, implementation, and continuous improvement; 5. All students have equal access to the program of study as well as early career/early college options; 6. Career and Technical Student Organizations are integral components of the program of study; 7. The LEA will maintain safe facilities and equipment aligned with the program of study goals; and 8. A process for continuous improvement has been established, which includes a model of evaluation and program improvement.	
LEA CTE Coordinator Signature:	Date:
LEA Chief School Officer Signature:	Date:

ACADEMIC AND TECHNICAL SKILL STANDARDS

List the academic, technical, and workplace skills and knowledge used to develop the CTE course.

Title and source of academic standards:

Common Core State Standards (CCSS)

The Common Core State Standards (CCSS) are national standards that set clear college- and career-ready expectations for kindergarten through 12th grade in English language arts/literacy and Mathematics. The standards help to ensure that students graduating from high school are prepared to take credit bearing introductory courses in two- or four-year college programs and enter the workforce. The standards were developed by the nation's governors and education commissioners, through their representative organizations, the National Governors Association Center for Best Practices (NGA) and the Council of Chief State School Officers (CCSSO). Teachers, parents, school administrators, and experts from across the country provided input into the development of the standards. The implementation of the Common Core, including how the standards are taught, the curriculum developed, and the materials used to support teachers as they help students reach the standards, is led entirely at the state and local levels. For more information on CCSS, please visit the link above.

Both CS in Algebra courses are aligned to Common Core Standards for Mathematics. CS in Algebra is also a model implementation of Common Core Standards for Mathematical Practice, offering explicit pedagogical recommendation across all eight practice standards. The standards alignment can be reviewed at https://code.org/curriculum/docs/algebra/standards

Title and source of technical skill standards:

Computer Science Teachers Association Standards (CSTA):

The Computer Science Standards provide a comprehensive set of standards for K-12 computer science education designed to strengthen computer science fluency and competency throughout primary and secondary schools. The standards are written in response to the pressing need to provide academic coherence between coursework and the rapid growth of computing and technology in the modern world, alongside the need for an educated public that can utilize and build that technology most effectively for the benefit of society. The standards have been vetted by dozens of partners at the national level through the CTSA standards taskforce. For more information on CSTA, please visit the link above.

Both CS in Algebra courses are aligned to CSTA (Computer Science Teacher's Association) standards across levels 1 (grades K-6) and 2 (grades 6-9)

International Society for Technology in Education (ISTE) Standards:

The ISTE Standards are the standards for learning, teaching, and leading in the digital age and are widely recognized and adopted worldwide. The ISTE Standards for Students are used to evaluate the skills and knowledge students need to learn effectively and live productively in an increasingly global and digital world. The standards have been vetted by hundreds of partners at the national level. For more information on the ISTE standards, please visit the link above.

Each of the courses within the Computer Science program of study have been benchmarked to the CSTA and ISTE standards. The standards alignment can be reviewed at the following web sites: http://www.bootstrapworld.org/materials/spring2016/Standards.shtml

Title and source of workplace or other skill standards, as applicable:

Common Career Technical Core (CCTC)
The Common Career Technical Core (CCTC) are national standards for Career & Technical Education (CTE) that help to inform the establishment of state standards and/or programs of study. The CCTC were developed by educators, school administrators, representatives from business and industry, faculty from higher education, as well as workforce and labor markets economists. The CCTC include a set of standards for each of the sixteen (16) Career Clusters and the corresponding Career Pathways that help to define what students should know and be able to do after completing instruction in a program of study. For more information on the CCTC, please visit the link above.

COURSE DESCRIPTIONS AND END-OF-COURSE ASSESSMENT

List the CTE middle school course title. Provide an overview the course and define what students should know and be able to demonstrate upon completion. Identify appropriate end-of-course assessment(s).

Course title:
STEM in Computer Science I

Course description (include prerequisites):
The STEM in Computer Science I course is a combination of Computer Science in Algebra Course A curriculum provided by Code.org (powered by Bootstrap), and lessons on the introduction to computer application using Microsoft Office software. It is offered as a marking period exploratory course for Grade 7 students. The Code.org coursework provides students with the foundational skills and knowledge to begin using computer programming as a tool to learn about and develop algebraic functions. Students will be introduced to a graphical programming language designed for Algebra instruction, through which they will gain a deeper understanding of the order of operations, create images with algebraic expressions, and learn a technique for creating functions called the Design Recipe. By the end of Course A students will have the tools necessary to turn word problems from their own Algebra class into functions that can be used as mini apps. The introduction to Computer Applications lessons will familiarize students with computers and their applications. Students will become familiar with a variety of computer applications, including word-processing, spreadsheets, and multimedia presentations.

Course knowledge and skills (what students will know and be able to do):

1. **Videogames and Coordinate Planes:** Students reverse-engineer a simple videogame into a series of coordinates, and explore Cartesian space. Once they are comfortable with

coordinates, they brainstorm their own games and begin programming simple arithmetic expressions with Evaluation Blocks.

2. **Contracts, Strings and Images:** Students are introduced to a set-mapping representation for functions, in which the function translates points from a Domain to a Range. Students generalize their understanding of functions to include Strings and Images.
3. **Defining Functions:** Students define values of various types, as well as linear functions.
4. **The Design Recipe:** Students are introduced to the process for deriving functions from Word Problems using worked-through examples, called the Design Recipe.
5. **Computer Application Software:** Students will create a document in Microsoft Word and understand the formatting functions. Students will be able to write functions in Microsoft Excel to perform basic calculations and format data tables. Students will create a presentation in Microsoft PowerPoint with legible content and images. Students will understand the file management of a computer Operating System.

End-of-Course Assessment(s):

☒ Teacher designed assessment
☐ LEA designed assessment
☐ Certification/credentialing exam (specify):
☐ Licensing exam (specify):
☐ Nationally recognized exam (specify):
☐ Other (specify):

COURSE DESCRIPTIONS AND END-OF-COURSE ASSESSMENT

List the CTE middle school course title. Provide an overview the course and define what students should know and be able to demonstrate upon completion. Identify appropriate end-of-course assessment(s).

Course title:
STEM in Computer Science II

Course description (include prerequisites):
The STEM in Computer Science II course is a combination of Computer Science in Algebra Course B curriculum provided by Code.org (powered by Bootstrap), and lessons on computer software applications using Microsoft Office. It is offered as a marking period exploratory course for Grade 8 students. The Code.org coursework builds on the skills students developed in STEM in Computer Science I through the development of a video game. Students will delve deeper into the intersection of Math and Computer Science by studying topics such as Boolean logic, piecewise functions, and collision detection with the Pythagorean Theorem, using these concepts to build supporting functions that will eventually drive the logic in their culminating game. The Computer Applications lessons will build on the computer applications knowledge developed in STEM in Computer Science I. Students will learn additional formatting tools and insertion of multimedia within word processing, spreadsheet, and presentation software.

Course knowledge and skills (what students will know and be able to do):

1. **Game Animation:** Students solve Word Problems that describe animation, and define functions that map character positions in their game from one frame to the next.
2. **Boundary Detection:** Students discover Boolean types and inequalities in the plane, and use them to create programs that test locations of a character on the screen. They then solve Word Problems that deal with Boundary-Detection, writing code to detect when a character has gone off-screen.
3. **Piecewise Functions:** Students use geometry and conditional branching to move their player characters in response to key-presses. The Word Problem for key-events describes a function that behaves differently under different sub-domains, requiring students to learn about Piecewise Functions.
4. **Collision Detection:** Students derive, discuss, and prove the Pythagorean Theorem, then use this theorem—in conjunction with Booleans—to detect collisions in their games.
5. **Computer Application Software:** Student will be able to create word documents while modifying their work environment using the header and footer, and incorporate advanced formatting such as adding tables. In Excel students will be able to use functions. In PowerPoint students will insert multimedia and learn advanced formatting such as animation.

End-of-Course Assessment(s):

☒ Teacher designed assessment
☐ LEA designed assessment
☐ Certification/credentialing exam (specify):
☐ Licensing exam (specify):
☐ Nationally recognized exam (specify):
☐ Other (specify):

COURSE CURRICULUM

Identify the method of technical and academic curriculum development (adopted, adapted, or developed in accordance with guidance from a program advisory committee).

POS technical and academic curriculum will be:

☐ Adopted (specify source):
☒ Adapted (specify source): Code.org CS in Algebra A and B with the addition of locally developed Computer Applications using Microsoft Office
☐ Developed locally (describe):
☐ Other (specify):

TEACHER CERTIFICATION

Provide valid teacher certification(s), candidate experience, pre-requisite and requisite licensure or certification requirement(s) for POS teachers.

POS teacher requirements include:

☒ Teacher certification(s) (list): Mathematics Education (Middle Level or Secondary); Science Education (Middle or Secondary); Business Education with emphasis on computer technology; Technology Education with emphasis on computer technology; or Skilled and Technical Sciences

(STS) Programming and Software Development ☐ Candidate experience (describe): ☐ Pre-requisite professional licensure or certification requirement(s) (list): ☐ Requisite professional licensure or certification requirement(s) (list): ☐ Other (describe):

MIDDLE SCHOOL-HIGH SCHOOL ARTICULATION
Describe how the CTE middle school course is aligned with one or more CTE high school programs of study. Describe how the school culture promotes career exploration and the opportunity for students to learn and apply both academic and technical skills.
Middle School-High School Alignment: Sussex Academy is an integrated grade 6-12 school. The STEM in Computer Science courses align with the Engineering Career Pathway within the STEM Career Cluster for grades 9-12. This course is one of the four exploratory courses offered at each grade level in the middle school. All students will be exposed to the hands on learning of Algebra (academic skills) within the context of computer programming (technical skills). The mathematics exposure will support student success in the PTLW Engineering POS at the high school which uses mathematic skills in an engineering context. It will also provide early exposure to computer programming, supporting the Computer Science Principles course offered at the high school.
Culture of Career-Readiness: The Sussex Academy Mission Statement is to prepare students for future academic success by providing an accelerated, supportive academic environment within a small school setting. At the request of the Perkins Advisory Committee, parents, guidance counselor, and administration, Sussex Academy implemented a Computer Science Advisory Committee to recommend how to provide students the opportunity to learn computer science and early exposure to computer programming. The recommendation from the committee was to provide students with a computer science course in grades 6-8 using the Code.org curriculum, convert the technology education courses from Engineering by Design to Project Lead the Way Gateway, and to implement the PLTW Computer Science Principles course as an elective in the Engineering pathway. Sussex Academy is also incorporating an Introduction to Computer Science course by code.org for 6th grade students. Sussex Academy values the importance of STEM in career readiness by including both computer science and technology education as exploratory courses for all 6-8th grade students and requiring the Introduction to Engineering Design for all 9th grade students.

CAREER AND TECHNICAL STUDENT ORGANIZATIONS	
Indicate the Career and Technical Student Organization (CTSO) affiliation by checking the appropriate box.	
☐ BPA	☐ FFA
☐ DECA	☐ HOSA
☐ FCCLA	☒ TSA

PROGRAM OF STUDY MATRIX

Complete the program of study matrix with high school partners to demonstrate the alignment of academic and technical courses, culminating early career and/or early college experiences at the high school level. *Attach the Program of Study Matrix*.
Access the Program of Study Matrix.

DEPARTMENT OF EDUCATION MIDDLE SCHOOL APPROVAL	
The following section will be completed by staff from the Delaware Department of Education, CTE & STEM Office and reported to the LEA as part of the CTE Middle School approval process.	
Date Delaware CTE Middle School Application Received:	
Local Education Agency (LEA): **School(s):**	**Middle School Course Start Date:**
LEA CTE Coordinator Name: **Phone:** **E-Mail Address:**	
Course Name/Course Code/Funding Level: **Grade Level:**	
CTE Program(s) of Study Alignment: High School: Program(s) of Study:	
CTE Program of Study Attachments: ☐ Middle School Matrix	
DDOE CTE & STEM Director Signature: Date:	
DDOE Chief Academic Officer Signature: Date:	

CS in Algebra

Code.org Curriculum Framework

Lesson 1: Video Games and Coordinate Planes	
Overview	Students discuss the components of their favorite video games and discover that they can be reduced to a series of coordinates. They then explore coordinates in Cartesian space, identifying the coordinates for the characters in a game at various points in time. Once they are comfortable with coordinates, they brainstorm their own games and create sample coordinate lists for different points in time in their own game.
Objectives	• Create a data model that describes a simple video game. • Describe the movements of videogame characters by their change in coordinates.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.5 , 6.NS.8 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 . **CSTA K-12 Computer Science Standards**: CT.L1:6-01 , CT.L2:14 .

Lesson 2: Evaluation Blocks and Arithmetic Expressions	
Overview	Students will begin using Evaluation Blocks to explore the concept of math as a language, and more specifically, a programming language. By composing arithmetic expressions with Evaluation Blocks, students will be able to visualize how expressions follow the order of operations.
Objectives	• Convert arithmetic expressions to and from code. • Use Evaluation Blocks to reflect the proper order of operations for an expression.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.5 , 6.NS.6 , 6.NS.8 , 6.EE.2 , A.SSE.1 , A.SSE.2 , A.SSE.4 , A.REI.1 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 3: Strings and Images

Lesson 3: Strings and Images	
Overview	To compute more than just numbers, students will need to learn about two new data types, Strings (any string of alphanumeric characters) and Images. Using these new data types, we'll compose programs that produce and manipulate images.
Objectives	• Write and evaluate expressions for generating Strings and Images.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , A.SSE.1 , A.SSE.2 , A.SSE.4 , A.REI.1 , F.IF.1 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 4: Contracts, Domain, and Range	
Overview	Contracts provide a way for students to better understand and discuss functions. Through this lesson, students will look at known functions and come up with the contracts that describe those functions.
Objectives	• Describe a function in terms of its name, domain, and range. • Create contracts for arithmetic and image-producing functions.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , A.SSE.1 , A.SSE.2 , F.IF.1 , F.IF.2 , F.IF.3 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 5: Writing Contracts	
Overview	Students will work their way through a number of new functions, first using each to solve a problem, and then writing a contract which describes it.
Objectives	• Decompose existing functions. • Write contracts that describe functions. • Experiment with basic geometric transformations.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.G.1 , A.SSE.1 , A.SSE.2 , F.IF.1 , F.IF.2 , F.IF.3 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 6: Defining Variables and Substitution

Lesson 6: Defining Variables and Substitution	
Overview	In this activity, students will learn to define variables that can be used to reference values and expressions. Once defined, their variables can be used repeatedly throughout a program as substitutes for the original values or expressions.
Objectives	• Define variables by giving them a name and assigning them a value or expression. • Use variables within Evaluation Blocks. • Describe a situation where using variables as substitutions for values or expressions is more efficient.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.EE.4 , A.SSE.1 , A.SSE.2 , A.CED.1 , A.CED.2 , F.IF.1 , F.IF.2 , F.IF.3 , F.LE.1 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 7: The Big Game - Variables	
Overview	Students get their first look at the inside of their own video games. They will start development by substituting in new Images, Strings, and Numbers for existing variables.
Objectives	• Substitute new values into existing variables of an existing program and describe the effects. • Examine the structure of an existing program.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.EE.4 , A.SSE.1 , A.SSE.2 , A.CED.1 , A.CED.2 , F.IF.1 , F.IF.2 , F.IF.3 , F.LE.1 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 8: Composite Functions	
Overview	In the past lessons students have defined variables which will allow them to easily write expressions that refer to the same value repeatedly. In this stage, they will write simple functions that, like variables, allow students to abstract out repetitious elements of their programs.
Objectives	• Analyze and use existing functions. • Modify existing functions. • Create new functions. • Create similar shapes by changing size parameters on functions.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 7.G.1 , 8.F.1 , 8.F.2 , A.SSE.1 , A.SSE.2 , A.CED.1 , A.CED.2 , F.IF.1 , F.IF.2 , F.IF.3 , F.IF.4 , F.IF.5 , F.IF.6 , F.LE.1 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 9: The Design Recipe	
Overview	In the last stage, students wrote some very simple functions - but more sophisticated functions demand a more thoughtful approach. The Design Recipe is a structured approach to writing functions that includes writing test cases to ensure that the function works as expected. Once students have mastered the Design Recipe process, they can apply it to any word problem they encounter.
Objectives	• Use the Design Recipe to identify dependent variables, independent variables, and constants.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , A.CED.1 , A.CED.2 , A.CED.3 , A.CED.4 , F.IF.1 , F.IF.2 , F.IF.3 , F.IF.4 , F.IF.5 , F.IF.6 , F.IF.7 , F.IF.9 , F.BF.1 , F.BF.2 , F.LE.1 , F.LE.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 10: Rocket Height	
Overview	Using the Design Recipe, students will work through a series of word problems about calculating the height of a rocket after a given number of seconds from launch. The functions they write will be used to animate the rocket launch.
Objectives	• Design functions to solve word problems. • Use the Design Recipe to write contracts, test cases, and function definitions.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , A.CED.1 , A.CED.2 , A.CED.3 , A.CED.4 , F.IF.1 , F.IF.2 , F.IF.3 , F.IF.4 , F.IF.5 , F.IF.6 , F.IF.7 , F.IF.9 , F.BF.1 , F.BF.2 , F.LE.1 , F.LE.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 11: Solving Word Problems with the Design Recipe	
Overview	Students will continue to practice the Design Recipe with a series of word problems.
Objectives	• Design functions to solve word problems. • Continue to practice writing contracts with more complex scenarios.

Lesson 11: Solving Word Problems with the Design Recipe	
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , A.CED.1 , A.CED.2 , A.CED.3 , A.CED.4 , F.IF.1 , F.IF.2 , F.IF.3 , F.IF.4 , F.IF.5 , F.IF.6 , F.IF.7 , F.IF.9 , F.BF.1 , F.BF.2 , F.LE.1 , F.LE.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 12: The Big Game - Animation	
Overview	Returning to the Big Game we started in stage 7, students will use the Design Recipe to develop functions that animate the Target and Danger sprites in their games.
Objectives	• Design functions to solve word problems. • Use the Design Recipe to write contracts, test cases, and function definitions.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , F.IF.1 , F.IF.2 , F.IF.4 , F.IF.5 , F.IF.6 , F.BF.1 , F.BF.2 , F.LE.1 , F.LE.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 13: Booleans and Logic	
Overview	Booleans are the fourth and final data type that students will learn about in this course. In this stage, students will learn about Boolean (true/false) values, and explore how they can be used to evaluate logical questions.
Objectives	• Evaluate simple Boolean expressions. • Evaluate complex Boolean expressions.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , A.REI.3 , A.REI.10 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 14: Boolean Operators	
Overview	Using Boolean operators, students will write code that compares values to make logical decisions.
Objectives	• Use Boolean operators to compare values. • Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons.

Lesson 14: Boolean Operators	
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 15: Sam the Bat	
Overview	Using Boolean operators, students will write code that checks the location of a sprite to make sure it doesn't go off-screen.
Objectives	• Use Boolean operators to compare values. • Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 16: The Big Game - Booleans	
Overview	Using the same logic from the previous lesson, students will write code that checks whether their Target and Danger sprites have left the screen. If their function determines that a sprite is no longer visible on screen, it will be reset to the opposite side.
Objectives	• Use Boolean operators to compare values. • Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 17: Conditionals and Piecewise Functions	
Overview	Currently, even when passing parameters to functions, our outputs follow a very rigid pattern. Now, suppose we want parameters with some values to create outputs using one pattern, but other values to use a different pattern. This is where conditionals are needed. In this stage students will learn how conditional statements can create more flexible programs.
Objectives	• Understand that piecewise functions evaluate the domain before calculating results. • Evaluate results of piecewise functions.

Lesson 17: Conditionals and Piecewise Functions	
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 , F.IF.7.b . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 18: Conditionals and Update Player	
Overview	Using conditionals, students will write functions and programs that change their behavior based on logical evaluation of input values.
Objectives	• Use Boolean operators to compare values. • Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons. • Write conditional statements that evaluate differently based on their input values.
Standards	**Common Core Math Standards**: 5.OA.1 , 5.OA.2 , 6.NS.8 , 6.EE.9 , 7.EE.4 , 8.F.1 , 8.F.2 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 19: Collision Detection and the Pythagorean Theorem	
Overview	Determining when objects on the screen touch is an important aspect of most games. In this lesson we'll look at how the Pythagorean Theorem and the Distance Formula can be used to measure the distance between two points on the plane, and then decide whether those two points (or game characters) are touching.
Objectives	• Demonstrate that circles will overlap if the distance between their centers is less than the sum of their radii. • Show that the distance of two points graphed in 2 dimensions can be represented as the hypotenuse of a right triangle. • Understand that the Pythagorean Theorem allows you to calculate the hypotenuse of a right triangle using the length of the two legs. • Apply the Pythagorean Theorem to calculate the distance between the centers of two objects.
Standards	**Common Core Math Standards**: 6.NS.8 , 7.EE.4 , 8.EE.2 , 8.F.1 , 8.F.2 , 8.G.7 , 8.G.8 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

Lesson 20: The Big Game - Collision Detection

Lesson 20: The Big Game - Collision Detection	
Overview	To finish up their video games, students will apply what they have learned in the last few stages to write the final missing functions. We'll start by using booleans to check whether keys were pressed in order to move the player sprite, then move on to applying the Pythagorean Theorem to determine when sprites are touching.
Objectives	• Apply the Distance Formula to detect when two points on a coordinate plane are near each other.
Standards	**Common Core Math Standards**: 6.NS.8 , 7.EE.4 , 8.EE.2 , 8.F.1 , 8.F.2 , 8.G.7 , 8.G.8 . **Common Core Math Practices**: MP.1 , MP.2 , MP.3 , MP.4 , MP.5 , MP.6 , MP.7 , MP.8 .

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Honors Chemistry **GRADE: 11**

Unit	Standards	Unit Concept/Essential Ideas	Assessments
Topic 1: Stoichiometric Relationships	Syllabus and cross-curricular links are provided in the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and attached as a pdf document.	Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Content Specific Vocabulary Atoms, Compounds, Mixtures, Chemical Equations, State Symbols, Changes of State, Conservation of Mass, Mole, Avogadro's Number, Relative Atomic Mass, Molar Mass, Percentage Composition, Molecular Formula, Empirical Formula, Limiting and Excess Reactants, Avogadro's Law, Molar Volume, Ideal Gas Law, Concentration, Standard Solution, Titration	Formative quizzes and summative tests are generated using both the IB Chemistry Questionbank (a database of prior exam questions) and questions from the Honors Chemistry textbook. Specimen Papers with example questions are available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Performance tasks are outlined in the the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. These include applications and skills, international mindedness and theory of knowledge connections, as well as utilizations and aims of concepts.

TEACHER'S NAME: Heather Moore **6/17**

Topic 2: Atomic Structure		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Content Specific Vocabulary Nucleons, Mass Spectrometer, Nuclear Symbol Notation, Isotopes, Emission Spectra, Orbital Theory, Aufbau Principle, Hund's Rule, Pauli Exclusion Principle, Electron Configuration, Orbital Diagram	
Topic 3: Periodicity		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Content Specific Vocabulary Nucleons, Mass Spectrometer, Nuclear Symbol Notation, Isotopes, Emission Spectra, Orbital Theory, Aufbau	

		Principle, Hund's Rule, Pauli Exclusion Principle, Electron Configuration, Orbital Diagram	
Topic 4: Chemical Bonding and Structure		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Content Specific Vocabulary Cation, Anion, Ionic Bond, Lattice Structure, Polyatomic Ion, Volatility, Solubility, Conductivity, Covalent Bond, Bond Length, Bond Strength, Polarity, Dipole Moment, Lewis Structure, Resonance Structure, VSEPR Theory. Allotrope, Intermolecular Force, London Forces, Dipole-dipole Forces, Hydrogen Bonding, Metallic Bonding, Alloy	
Topic 5: Energetics/ Thermochemistry		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Some IB Chemistry concepts in this topic are not covered in Honors Chemistry. These concepts have been removed from the Content Specific Vocabulary. Content Specific Vocabulary Heat, Temperature, Enthalpy Change, Calorimetry, Specific Heat Capacity, Endothermic, Exothermic	
Topic 6: Chemical Kinetics		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Some IB Chemistry concepts in this topic are not covered in Honors Chemistry. These concepts have been removed from the Content Specific Vocabulary. Content Specific Vocabulary Collision Theory, Rate of Reaction, Activation Energy, Catalyst, Energy Profiles	

Topic 7: Equilibrium		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Some IB Chemistry concepts in this topic are not covered in Honors Chemistry. These concepts have been removed from the Content Specific Vocabulary.	

		Content Specific Vocabulary Closed System, Equilibrium Constant, Le Chatelier's Principle	
Topic 8: Acids and Bases		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Some IB Chemistry concepts in this topic are not covered in Honors Chemistry. These concepts have been removed from the Content Specific Vocabulary. Content Specific Vocabulary Bronsted-Lowry Theory, Amphiprotic, Conjugate Acid-base Pair, Indicator, pH, pH meter, Universal Indicator, Acid/Base Strength	
Topic 11: Measurement and Data Processing		Concepts and Essential Ideas are outlined in detail throughout the IB Chemistry Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Some IB Chemistry concepts in this topic are not covered in Honors Chemistry. These concepts have been removed from the Content Specific Vocabulary. Content Specific Vocabulary Qualitative Data, Quantitative Data, Random Error, Systematic Error, Precision, Accuracy, Absolute Uncertainty, Percentage Error, Significant Figures, Linear Function, Gradient	

CHEMISTRY
HIGHER LEVEL
PAPER 1

SPECIMEN PAPER

1 hour

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is *[40 marks]*.

17 pages

The Periodic Table

Key
Atomic number **Element** Relative atomic mass

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.01																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.90
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
6	55 **Cs** 132.91	56 **Ba** 137.33	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (270)	108 **Hs** (269)	109 **Mt** (278)	110 **Ds** (281)	111 **Rg** (281)	112 **Cn** (285)	113 **Unt** (286)	114 **Uug** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

1. Which changes of state are endothermic processes?

I. Condensing
II. Melting
III. Subliming

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

2. What is the sum of the coefficients when the equation for the combustion of ammonia is balanced using the smallest possible whole numbers?

$$\_\_\_ NH_3(g) + \_\_\_ O_2(g) \rightarrow \_\_\_ N_2(g) + \_\_\_ H_2O(g)$$

A. 6

B. 12

C. 14

D. 15

3. 5.00 g of calcium carbonate, when heated, produced 2.40 g of calcium oxide. Which is the correct expression for the percentage yield of calcium oxide? ($M_r(CaCO_3) = 100$; $M_r(CaO) = 56$.)

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

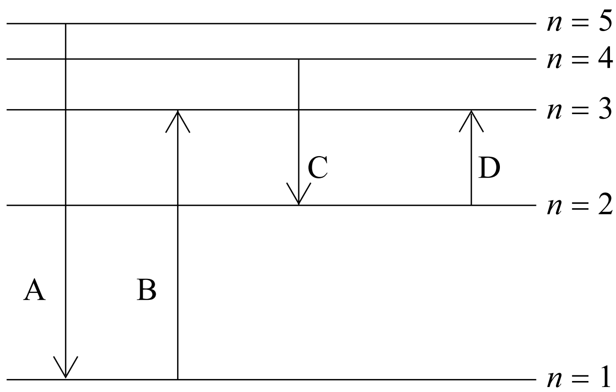
A. $\frac{56 \times 5.00 \times 100}{2.40}$

B. $\frac{2.40 \times 100 \times 100}{56 \times 5.00}$

C. $\frac{56 \times 5.00 \times 100}{2.40 \times 100}$

D. $\frac{2.40 \times 100}{56 \times 5.00}$

4. Which electronic transition would absorb the radiation of the shortest wavelength?



5. Which is the electron configuration of the ion Fe^{2+}?

A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4\ 4s^2$

D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

6. Which element is in group 2?

	1st ionization energy / kJ mol^{-1}	**2nd ionization energy / kJ mol^{-1}**	**3rd ionization energy / kJ mol^{-1}**	**4th ionization energy / kJ mol^{-1}**
A.	1402	2856	4578	7475
B.	590	1145	4912	6474
C.	403	2632	3900	5080
D.	578	1817	2745	11578

7. Which element is in the f-block of the periodic table?

A. Be

B. Ce

C. Ge

D. Re

8. Which property increases down group 1 of the periodic table?

A. Melting point

B. First ionization energy

C. Atomic radius

D. Electronegativity

9. What is the overall charge on the complex ion formed by iron(II) and six cyanide ions, CN^-?

A. 4+

B. 4–

C. 8–

D. 8+

10. Which statement about transition metal complex ions is correct?

A. The difference in energy of the d orbitals is independent of the oxidation state of the metal.

B. The colour of the complex is caused by light emitted when an electron falls back from a higher to a lower energy level.

C. The colour of the complex is the colour of the light absorbed when an electron moves from a lower to a higher energy level.

D. The difference in energy of the d orbitals depends on the nature of the ligand.

11. Which is the best description of ionic bonding?

A. Electrostatic attraction between oppositely charged ions

B. Electrostatic attraction between positive ions and electrons

C. Electrostatic attraction of nuclei towards shared electrons in the bond between the nuclei

D. Electrostatic attraction between nuclei

12. Which intermolecular forces are covered by the term van der Waals'?

I. London dispersion forces

II. Dipole-induced dipole forces

III. Dipole-dipole forces

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

13. Which bond is the **least** polar?

A. C=O in CO_2

B. C–H in CH_4

C. C–Cl in CCl_4

D. N–H in CH_3NH_2

14. Which pair of compounds contains 9 sigma, σ, and 2 pi, π, bonds in each molecule?

A. CH_3CO_2H and $CH_3CH(OH)CH_3$

B. CH_3COCH_3 and $CH_3COOCH_2CH_3$

C. $CHCCH_2CH_3$ and $CH_2CHCHCH_2$

D. CH_3COH and CH_3CH_2OH

15. Which molecule contains an atom with sp^2 hybridization?

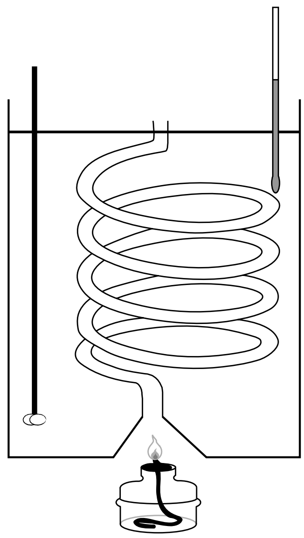
A. $CH_3CH_2CH_2NH_2$

B. $CH_3CH_2CH_2CN$

C. $CH_3CH_2CH_2CH_2Cl$

D. $CH_3CH_2CHCHCH_3$

16. When 0.46 g of ethanol is burned under a water-filled calorimeter, the temperature of 500 g of water is raised by 3.0 K. (Molar mass of ethanol = 46 g mol^{-1}; specific heat capacity of water = 4.18 J g^{-1} K^{-1}; $q = mc\Delta T$.)



What is the expression for the enthalpy of combustion, ΔH_c, in kJ mol^{-1}?

A. $-\dfrac{500 \times 4.18 \times 3.0 \times 46}{0.46}$

B. $-\dfrac{500 \times 4.18 \times (273 + 3.0) \times 46}{0.46 \times 1000}$

C. $-\dfrac{500 \times 4.18 \times 3.0 \times 46}{0.46 \times 1000}$

D. $-\dfrac{0.46 \times 1000}{500 \times 4.18 \times 3.0 \times 46}$

17. Given the following information, what is the standard enthalpy of formation, $\Delta H^{\ominus}{}_{f}$, of methane?

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = E \text{ kJ}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H = F \text{ kJ}$$
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = G \text{ kJ}$$

A. E + F + G

B. E + F – G

C. E + 2F + G

D. E + 2F – G

18. Which combination has the most endothermic lattice enthalpy?

	Radius of positive ion / nm	**Radius of negative ion / nm**	**Charge on positive ion**	**Charge on negative ion**
A.	0.100	0.185	2+	2–
B.	0.102	0.180	1+	1–
C.	0.149	0.180	1+	1–
D.	0.100	0.140	2+	2–

19. In which reaction is the value of ΔS positive?

A. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

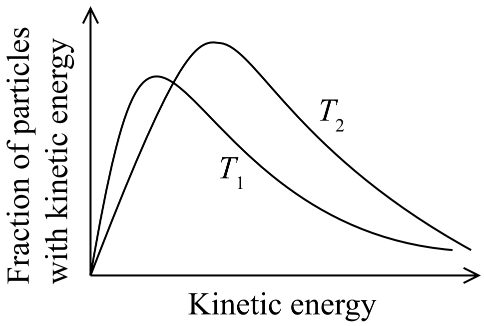
B. $H_2O(g) \rightarrow H_2O(s)$

C. $2KI(aq) + Pb(NO_3)_2(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$

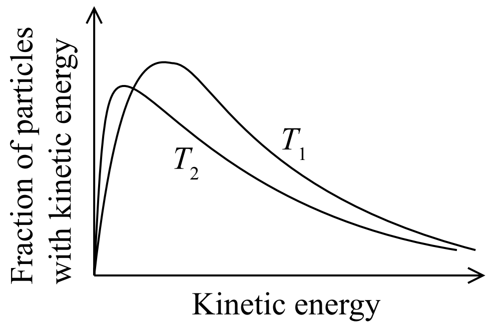
D. $2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$

20. Which graph shows the Maxwell-Boltzmann energy distribution of a same amount of a gas at two temperatures, where T_2 is greater than T_1?

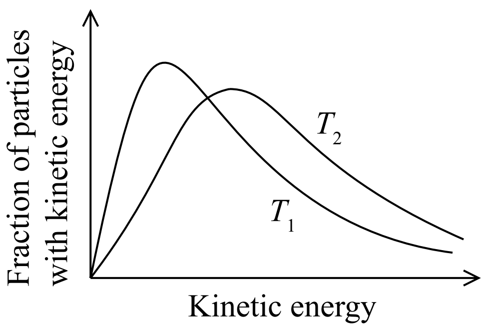
A.



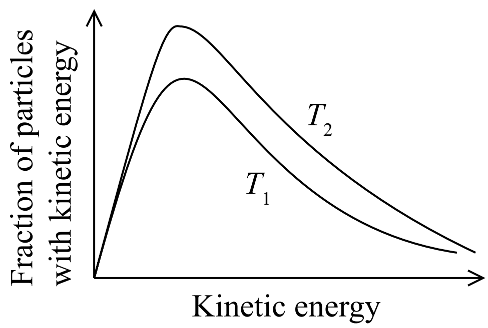
B.



C.



D.



21. Which changes increase the rate of this reaction, other conditions remaining constant?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

I. Using larger lumps of calcium carbonate

II. Increasing the temperature of the reaction mixture

III. Increasing the concentration of hydrochloric acid

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

22. The rate information below was obtained for the following reaction at a constant temperature.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

Initial [H_2O_2 (aq)] / mol dm^{-3}	**Initial [H^+(aq)] / mol dm^{-3}**	**Initial [I^-(aq)] / mol dm^{-3}**	**Initial rate of reaction / mol dm^{-3} s^{-1}**
0.005	0.05	0.015	1.31×10^{-6}
0.01	0.05	0.015	2.63×10^{-6}
0.01	0.05	0.03	5.25×10^{-6}
0.01	0.1	0.03	5.25×10^{-6}

What is the overall order of the reaction?

A. 0

B. 1

C. 2

D. 3

23. Which reaction is **most** likely to be spontaneous?

	Enthalpy change	**Entropy**
A.	exothermic	entropy decreases
B.	exothermic	entropy increases
C.	endothermic	entropy decreases
D.	endothermic	entropy increases

24. Which conditions give the greatest equilibrium yield of methanal, $H_2CO\,(g)$?

$$CO(g) + H_2(g) \rightleftharpoons H_2CO(g) \qquad \Delta H = -1.8\,kJ$$

	Pressure	Temperature
A.	high	low
B.	high	high
C.	low	high
D.	low	low

25. Which combination of temperature and equilibrium constant is most typical of a reaction going to completion? (Refer to the equation $\Delta G^{\ominus} = -RT \ln K$.)

	Temperature	Equilibrium constant
A.	high	> 1
B.	high	< 1
C.	low	> 1
D.	low	< 1

26. Which of the following is **not** amphiprotic?

A. H_2O

B. HPO_4^{2-}

C. $H_2PO_4^{-}$

D. H_3O^{+}

27. The pH of a solution changes from 3 to 5. What happens to the concentration of hydrogen ions?

A. It increases by a factor of 2.

B. It increases by a factor of 100.

C. It decreases by a factor of 2.

D. It decreases by a factor of 100.

28. Which statement is correct about a Lewis base?

A. It is an electron pair donor and can act as a nucleophile.

B. It is an electron pair acceptor and can act as a nucleophile.

C. It is an electron pair donor and can act as an electrophile.

D. It is an electron pair acceptor and can act as an electrophile.

29. Which mixture forms a buffer solution with a pH < 7?

A. $50\,cm^3$ $0.10\,mol\,dm^{-3}$ $NH_4Cl(aq)$ + $50\,cm^3$ $0.10\,mol\,dm^{-3}$ $NH_3(aq)$

B. $50\,cm^3$ $0.10\,mol\,dm^{-3}$ $HCl(aq)$ + $100\,cm^3$ $0.10\,mol\,dm^{-3}$ $NH_3(aq)$

C. $50\,cm^3$ $0.10\,mol\,dm^{-3}$ $NaOH(aq)$ + $100\,cm^3$ $0.10\,mol\,dm^{-3}$ $CH_3COOH(aq)$

D. $50\,cm^3$ $0.10\,mol\,dm^{-3}$ $H_2SO_4(aq)$ + $100\,cm^3$ $0.10\,mol\,dm^{-3}$ $NH_3(aq)$

30. The equations below represent reactions involved in the Winkler method for determining the concentration of dissolved oxygen in water:

$$2Mn(OH)_2(s) + O_2(aq) \rightarrow 2MnO(OH)_2(s)$$
$$MnO(OH)_2(s) + 2H_2SO_4(aq) \rightarrow Mn(SO_4)_2(s) + 3H_2O(l)$$
$$Mn(SO_4)_2(s) + 2I^-(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2SO_4^{2-}(aq)$$
$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

What is the amount, in mol, of thiosulfate ions, $S_2O_3^{2-}$(aq), needed to react with the iodine, I_2(aq), formed by 1.00 mol of dissolved oxygen?

A. 2.00

B. 3.00

C. 4.00

D. 6.00

31. What are the products when molten sodium chloride is electrolysed?

	Cathode	**Anode**
A.	hydrogen	chlorine
B.	sodium	chloride
C.	sodium	chlorine
D.	chlorine	sodium

32. $E^{\ominus}$ values for some half-equations are given below.

$$Mn^{2+}(aq) + 2e^{-} \rightleftharpoons Mn(s) \qquad E^{\ominus} = -1.18\,V$$
$$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s) \qquad E^{\ominus} = -0.45\,V$$
$$Pb^{2+}(aq) + 2e^{-} \rightleftharpoons Pb(s) \qquad E^{\ominus} = -0.13\,V$$

Which reaction is spontaneous under standard conditions?

A. $Fe^{2+}(aq) + Mn(s) \rightarrow Fe(s) + Mn^{2+}(aq)$

B. $Mn^{2+}(aq) + Pb(s) \rightarrow Mn(s) + Pb^{2+}(aq)$

C. $Fe^{2+}(aq) + Pb(s) \rightarrow Fe(s) + Pb^{2+}(aq)$

D. $Mn^{2+}(aq) + Fe(s) \rightarrow Mn(s) + Fe^{2+}(aq)$

33. 50.0 cm^3 of 0.50 mol dm^{-3} aqueous copper(II) sulfate, $CuSO_4$(aq), is electrolysed using a current of 0.50 A for 30 minutes. What mass of copper, in g, is deposited on the cathode?
(M(Cu) = 64 g mol^{-1}; Faraday's constant (F) = 96500 C mol^{-1}.)

A. $\frac{50.0 \times 0.50 \times 64}{1000}$

B. $\frac{0.50 \times 30 \times 64}{96500 \times 2}$

C. $\frac{0.50 \times 30 \times 60 \times 64}{96500 \times 2}$

D. $\frac{50.0 \times 0.50 \times 64}{1000 \times 2}$

34. Which is propyl propanoate?

A. $CH_3CH_2CH_2OOCCH_2CH_3$

B. $CH_3CH_2CH_2COOCH_2CH_3$

C. $CH_3CH_2CH_2COCH_2CH_3$

D. $CH_3CH_2CH_2OCH_2CH_2CH_3$

35. Which could form an addition polymer?

A. $H_2NCH_2CHCHCH_2NH_2$

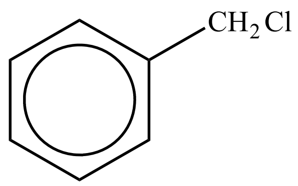
B. $H_2N(CH_2)_6CO_2H$

C. $HO(CH_2)_2CO_2H$

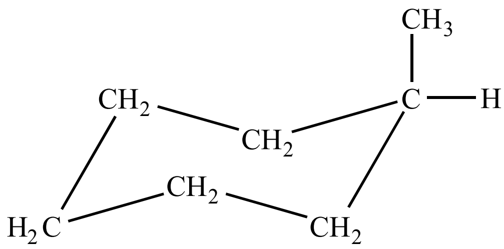
D. $H_2N(CH_2)_6NH_2$

36. Which benzene derivative can be formed from methylbenzene by electrophilic substitution?

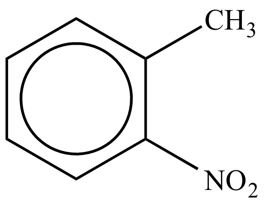
A.



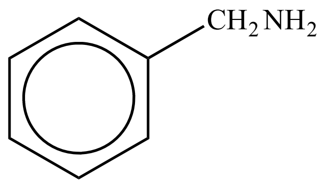
B.



C.



D.



37. Which compound has two enantiomeric forms?

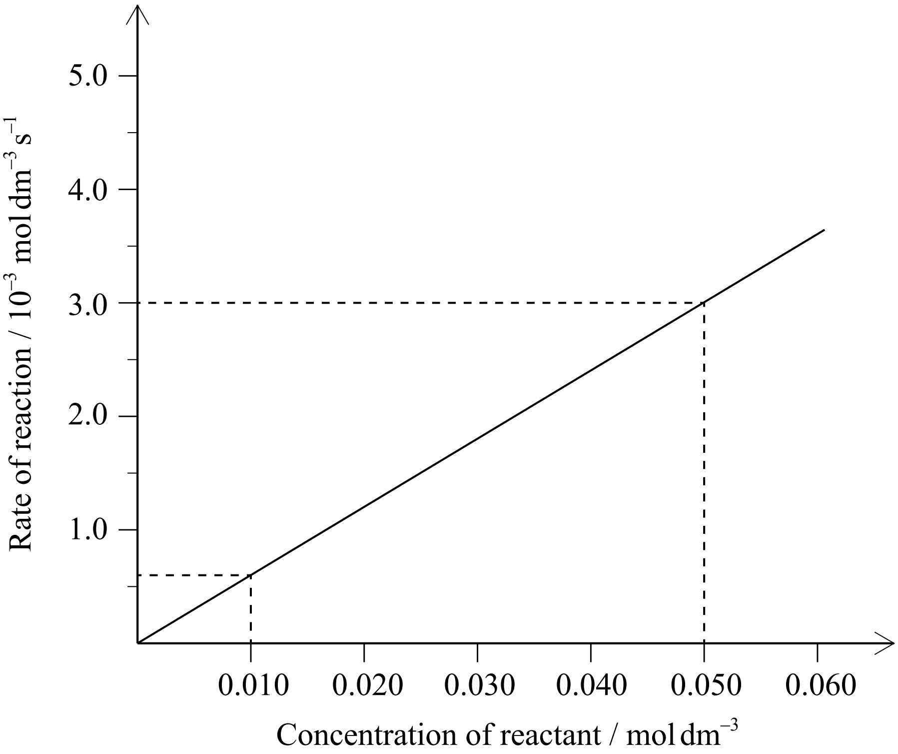
A. $CH_3CH_2CBr_2CH_3$

B. $CH_3CH_2CHBrCH_3$

C. $CH_3(CH_2)_2CH_2Br$

D. $CH_3CH_2CHBrCH_2CH_3$

38. Which combination in the table correctly states the value and units of the gradient?



	Value	Units
A.	$\frac{3.0\times10^{-3}-0.6\times10^{-3}}{0.050-0.010}$	s^{-1}
B.	$\frac{3.0\times10^{-3}-0.6\times10^{-3}}{0.050-0.010}$	s
C.	$\frac{0.050-0.010}{3.0\times10^{-3}-0.6\times10^{-3}}$	s^{-1}
D.	$\frac{0.050-0.010}{3.0\times10^{-3}-0.6\times10^{-3}}$	s

39. Which technique involves the absorption of radiation by bonds between atoms?

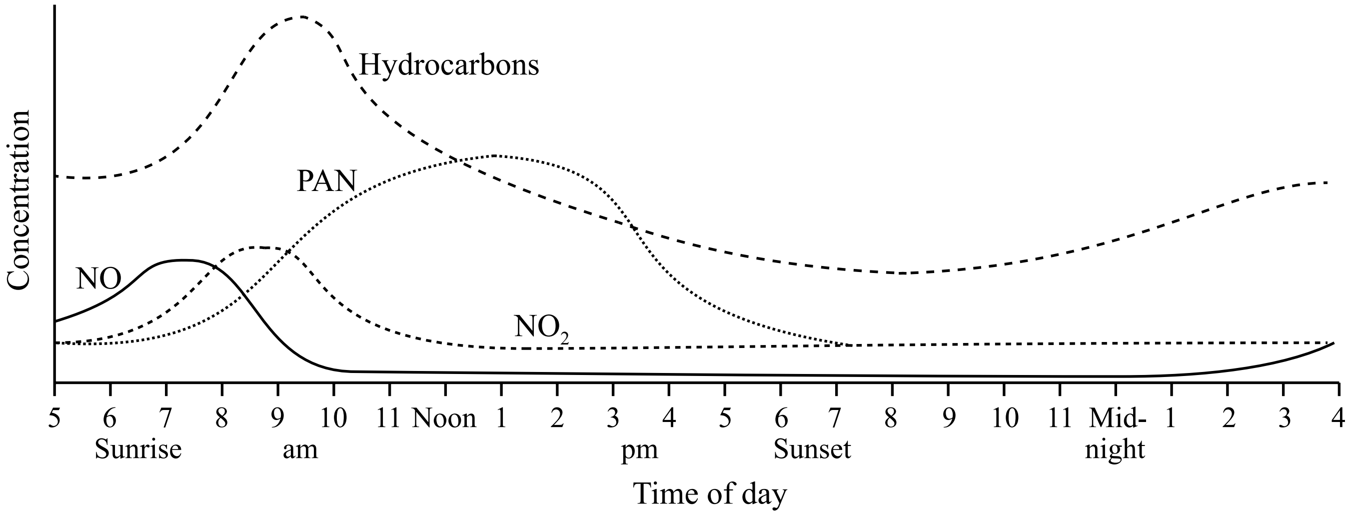
A. ^{1}H NMR

B. Infrared spectroscopy

C. X-ray crystallography

D. Mass spectrometry

40. The graph shows the concentration of some pollutants in a city over a 24-hour period.



Which of the following could **not** be inferred from the graph?

A. Hydrocarbons cause less harm to health than PAN.

B. An increase in hydrocarbons is caused by the morning rush hour.

C. PAN concentration increases as the intensity of sunlight increases.

D. NO_2 production follows the production of NO.

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2 pages

1.	C	16.	C	31.	C	46.	–
2.	D	17.	D	32.	A	47.	–
3.	B	18.	D	33.	C	48.	–
4.	B	19.	A	34.	A	49.	–
5.	A	20.	C	35.	A	50.	–
6.	B	21.	C	36.	C	51.	–
7.	B	22.	C	37.	B	52.	–
8.	C	23.	B	38.	A	53.	–
9.	B	24.	A	39.	B	54.	–
10.	D	25.	A	40.	A	55.	–
11.	A	26.	D	41.	–	56.	–
12.	D	27.	D	42.	–	57.	–
13.	B	28.	A	43.	–	58.	–
14.	C	29.	C	44.	–	59.	–
15.	D	30.	C	45.	–	60.	–

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CHEMISTRY
HIGHER LEVEL
PAPER 2

Candidate session number

SPECIMEN PAPER

Examination code

2 hours 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the *Chemistry data booklet* is required for this paper.
- The maximum mark for this examination paper is *[95 marks]*.

29 pages

*Answer **all** questions. Write your answers in the boxes provided.*

1. Two IB students carried out a project on the chemistry of bleach.

(a) The bleach contained a solution of sodium hypochlorite, NaClO(aq). The students determined experimentally the concentration of hypochlorite ions, ClO^-, in the bleach:

Experimental procedure:

- The bleach solution was first diluted by adding 25.00 cm^3 of the bleach to a 250 cm^3 volumetric flask. The solution was filled to the graduation mark with deionized water.

- 25.00 cm^3 of this solution was then reacted with excess iodide in acid.

$$ClO^-(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow Cl^-(aq) + I_2(aq) + H_2O(l)$$

- The iodine formed was titrated with 0.100 mol dm^{-3} sodium thiosulfate solution, $Na_2S_2O_3$(aq), using starch indicator.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The following data were recorded for the titration:

	First titre	**Second titre**	**Third titre**
Final burette reading of 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) (in cm^3 ± 0.05)	23.95	46.00	22.15
Initial burette reading of 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) (in cm^3 ± 0.05)	0.00	23.95	0.00

(i) Calculate the volume, in cm^3, of 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) required to react with the iodine to reach the end point. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(ii) Calculate the amount, in mol, of $Na_2S_2O_3$(aq) that reacts with the iodine. *[1]*

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. . . .

(iii) Calculate the concentration, in $mol\,dm^{-3}$, of hypochlorite ions in the **diluted** bleach solution. *[1]*

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. . . .
. . . .

(iv) Calculate the concentration, in $mol\,dm^{-3}$, of hypochlorite ions in the **undiluted** bleach solution. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(b) Some of the group 17 elements, the halogens, show variable valency.

(i) Deduce the oxidation states of chlorine and iodine in the following species. *[1]*

NaClO:

. . . .

I_2:

. . . .

(ii) Deduce, with a reason, the oxidizing agent in the reaction of hypochlorite ions with iodide ions in part (a). *[1]*

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(iii) From a health and safety perspective, suggest why it is not a good idea to use hydrochloric acid when acidifying the bleach. *[1]*

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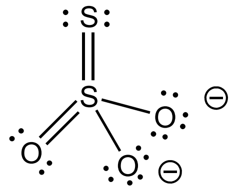
(This question continues on the following page)

(Question 1 continued)

(iv) The thiosulfate ion, $S_2O_3^{2-}$, is an interesting example of oxidation states. The sulfur atoms can be considered to have an oxidation state of +6 on one atom and –2 on the other atom. Discuss this statement in terms of your understanding of oxidation state. *[2]*



Lewis (electron dot) structure of thiosulfate

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(This question continues on the following page)

(Question 1 continued)

(c) The various changes that have been made to the definitions of oxidation and reduction show how scientists often broaden similarities to general principles.

Combustion is also a redox type of reaction.

With reference to the combustion reaction of methane, explore **two** different definitions of oxidation, choosing one which is valid and one which may be considered not valid. *[2]*

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

Valid:

. . . .

. . . .

. . . .

Not valid:

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(d) (i) State the **condensed** electron configuration of sulfur. *[1]*

. . . .

(ii) Deduce the orbital diagram of sulfur, showing all the orbitals present in the diagram. *[1]*

2. One of the main constituents of acid deposition is sulfuric acid, H_2SO_4. This acid is formed from the sulfur dioxide pollutant, SO_2.

A mechanism proposed for its formation is:

$$HO\bullet(g) + SO_2(g) \rightarrow HOSO_2(g)$$
$$HOSO_2(g) + O_2(g) \rightarrow HOO\bullet(g) + SO_3(g)$$
$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

(a) State what the symbol (•) represents in the species shown in this mechanism. *[1]*

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(b) Consider the following equilibrium between the two oxides of sulfur, sulfur dioxide and sulfur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -198\,kJ$$

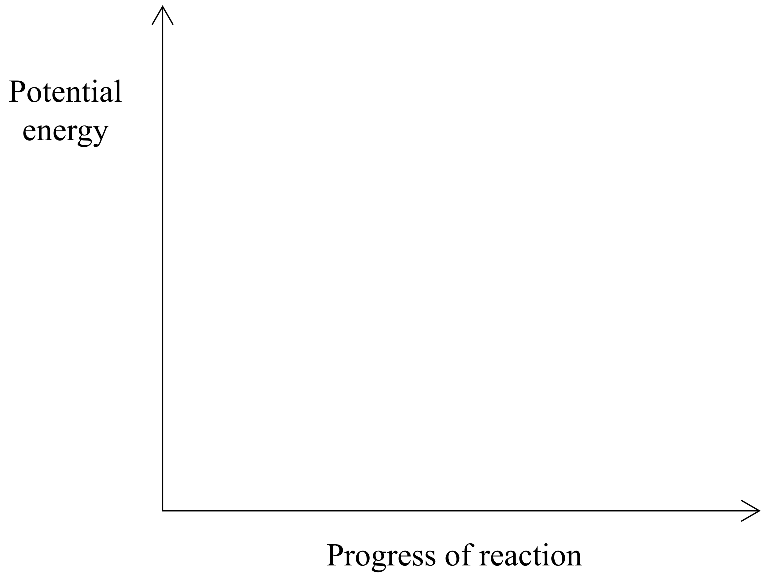
Predict, with a reason, in which direction the position of equilibrium will shift for each of the changes listed below. *[3]*

Change	**Shift**	**Reason**
Increase in temperature	. . . .	. . . .
Increase in pressure	. . . .	. . . .
Addition of a catalyst to the mixture	. . . .	. . . .

(This question continues on the following page)

(Question 2 continued)

(c) Sketch the potential energy profile for the forward reaction in part (b) to show the effect of a catalyst on the activation energy, E_{act}. *[2]*



(d) Other compounds present in acid rain are formed from nitrogen dioxide, NO_2. Formulate an equation for the reaction of nitrogen dioxide with water. *[1]*

(e) With reference to section 9 of the data booklet, explain the difference between the atomic radius and the ionic radius of nitrogen. *[1]*

3. A 0.12 $mol\,dm^{-3}$ sodium methanoate solution dissociates completely into its ions.

(a) Formulate the equation, including state symbols, for the equilibrium reaction of the hydrolysis of the methanoate anion. *[1]*

. . . .

Sections 1 and 21 of the data booklet may be used for parts (b) to (e).

(b) Calculate the value of K_a, the acid dissociation constant at 298 K, for an aqueous solution of methanoic acid. *[1]*

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(c) Calculate the value of K_b, the base dissociation constant, for the conjugate base. *[1]*

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(This question continues on the following page)

(Question 3 continued)

(d) Determine the concentration, in $mol\,dm^{-3}$, of hydroxide ion, $[OH^{-}(aq)]$, in the original $0.12\,mol\,dm^{-3}$ sodium methanoate solution, mentioning **one** assumption made. *[3]*

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(e) Calculate the pH of the $0.12\,mol\,dm^{-3}$ sodium methanoate solution. *[2]*

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4. 1-iodoethane reacts with sodium hydroxide.

(a) Explain the mechanism of this reaction, using curly arrows to represent the movement of electron pairs and showing any stereochemical features of the reaction mechanism. *[4]*

(b) State the rate expression for this reaction and identify the molecularity of the rate-determining step (RDS). *[2]*

Rate expression:

. . . .

Molecularity of RDS:

. . . .

(This question continues on the following page)

(Question 4 continued)

(c) Suggest why polar, aprotic solvents are more suitable for S_N2 reactions whereas polar, protic solvents favour S_N1 reactions. *[2]*

S_N2:

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S_N1:

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(d) Deduce, with a reason, if water or DMF (N,N-Dimethylformamide, $HCON(CH_3)_2$) is a better solvent for this reaction. *[1]*

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(e) Describe what you understand by the term *frequency (pre-exponential) factor, A*. *[1]*

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(This question continues on the following page)

(Question 4 continued)

(f) The activation energy, E_a, for the reaction of 1-iodoethane with sodium hydroxide is $87.0\,kJ\,mol^{-1}$, and the frequency (pre-exponential) factor, A, is $2.10 \times 10^{11}\,mol^{-1}\,dm^3\,s^{-1}$.

Calculate the rate constant, *k*, of the reaction at 25 °C, indicating the units of *k*, and giving a reason for your choice. *[2]*

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5. Many automobile manufacturers are developing vehicles that use hydrogen as a fuel.

(a) Suggest why such vehicles are considered to cause less harm to the environment than those with internal combustion engines. *[1]*

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(b) Hydrogen can react with ethene to form ethane.

$$H_2(g) + C_2H_4(g) \rightarrow C_2H_6(g)$$

Using average bond enthalpies at 298 K from section 11 of the data booklet, calculate the change in enthalpy, ΔH, in $kJ\,mol^{-1}$, for this reaction. *[3]*

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6. Ozone, dinitrogen monoxide, CFCs, sulfur hexafluoride and methane are all examples of greenhouse gases.

(a) (i) Draw one valid Lewis (electron dot) structure for each molecule of the greenhouse gases listed below. *[2]*

	Lewis (electron dot) structure
Ozone	
Sulfur hexafluoride	

(ii) Deduce the name of the electron domain geometry and the molecular geometry for each molecule listed below. *[2]*

	Electron domain geometry	Molecular geometry
Ozone	. . . .	. . . .
Sulfur hexafluoride	. . . .	. . . .

(This question continues on the following page)

(Question 6 continued)

(iii) Identify which molecule(s) given in part (a) (i) has/have an extended octet of electrons. *[1]*

. . . .

(iv) State the bond angles for each species in part (a) (ii). *[1]*

Ozone:

. . . .

Sulfur hexafluoride:

. . . .

(v) Draw all the resonance structures of ozone. Lone pairs should be shown. *[1]*

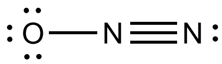
(This question continues on the following page)

(Question 6 continued)

(b) Nitrous oxide can be represented by different Lewis (electron dot) structures.

(i) Deduce the formal charge (FC) of the nitrogen and oxygen atoms in three of these Lewis (electron dot) structures, **A**, **B** and **C**, represented below. *[2]*

LHS: atom on left-hand side; RHS: atom on right-hand side.

	Lewis (electron dot) structure	**FC of O on LHS**	**FC of central N**	**FC of N on RHS**
A				
B				
C				

(ii) FC can be useful in electron book-keeping, but electronegativity values are ignored when FCs are assigned.

Based on the assignment of FCs of the atoms in part (i), deduce which Lewis (electron dot) structure of N_2O (**A**, **B** or **C**) is expected to be the preferred structure. Explore why another factor needs to be considered. *[2]*

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(This question continues on the following page)

(Question 6 continued)

(c) Ozone in the atmosphere can be formed from the combustion of methane.

(i) State the equation for this combustion reaction. *[1]*

. . . .

(ii) Calculate the standard enthalpy change for the reaction, $\Delta H^{\ominus}$, in $kJ\,mol^{-1}$, using the thermodynamic data in section 12 of the data booklet and the information given below. *[1]*

$O_3(g)$
$\Delta H_f^{\ominus} = +142.3\,kJ\,mol^{-1}$

. . . .

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. . . .

(iii) State why the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, for oxygen is not given. *[1]*

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(This question continues on the following page)

(Question 6 continued)

(iv) Calculate the standard entropy change for the reaction, $\Delta S^{\ominus}$, in $J K^{-1} mol^{-1}$, using the thermodynamic data in section 12 of the data booklet and the information given below. *[1]*

$O_2(g)$	$O_3(g)$
$S^{\ominus} = +205.0 J K^{-1} mol^{-1}$	$S^{\ominus} = +237.6 J K^{-1} mol^{-1}$

. . . .
. . . .
. . . .

(v) Deduce the standard change in Gibbs Free Energy, $\Delta G^{\ominus}$, in $kJ mol^{-1}$, for this reaction at 298 K. *[1]*

. . . .
. . . .
. . . .

(vi) Deduce, giving a reason, whether the reaction is spontaneous or non-spontaneous at this temperature. *[1]*

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(This question continues on the following page)

(Question 6 continued)

(d) (i) The concentration of ozone in the upper atmosphere is maintained by the following three reactions, I, II and III.

I $O_2 \xrightarrow{hv} 2O\bullet$

II $O_2 + O\bullet \rightarrow O_3$

III $O_3 \xrightarrow{hv} O_2 + O\bullet$

Explain by reference to the bonding in O_2 and O_3, which of the reactions, I or III, needs more energy. *[3]*

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(ii) Using dichlorodifluoromethane, CCl_2F_2, as an example, outline the reactions in which ozone depletion occurs in the upper atmosphere. Formulate an equation for each step in this process and explain the initial step by reference to the bonds in CCl_2F_2. *[5]*

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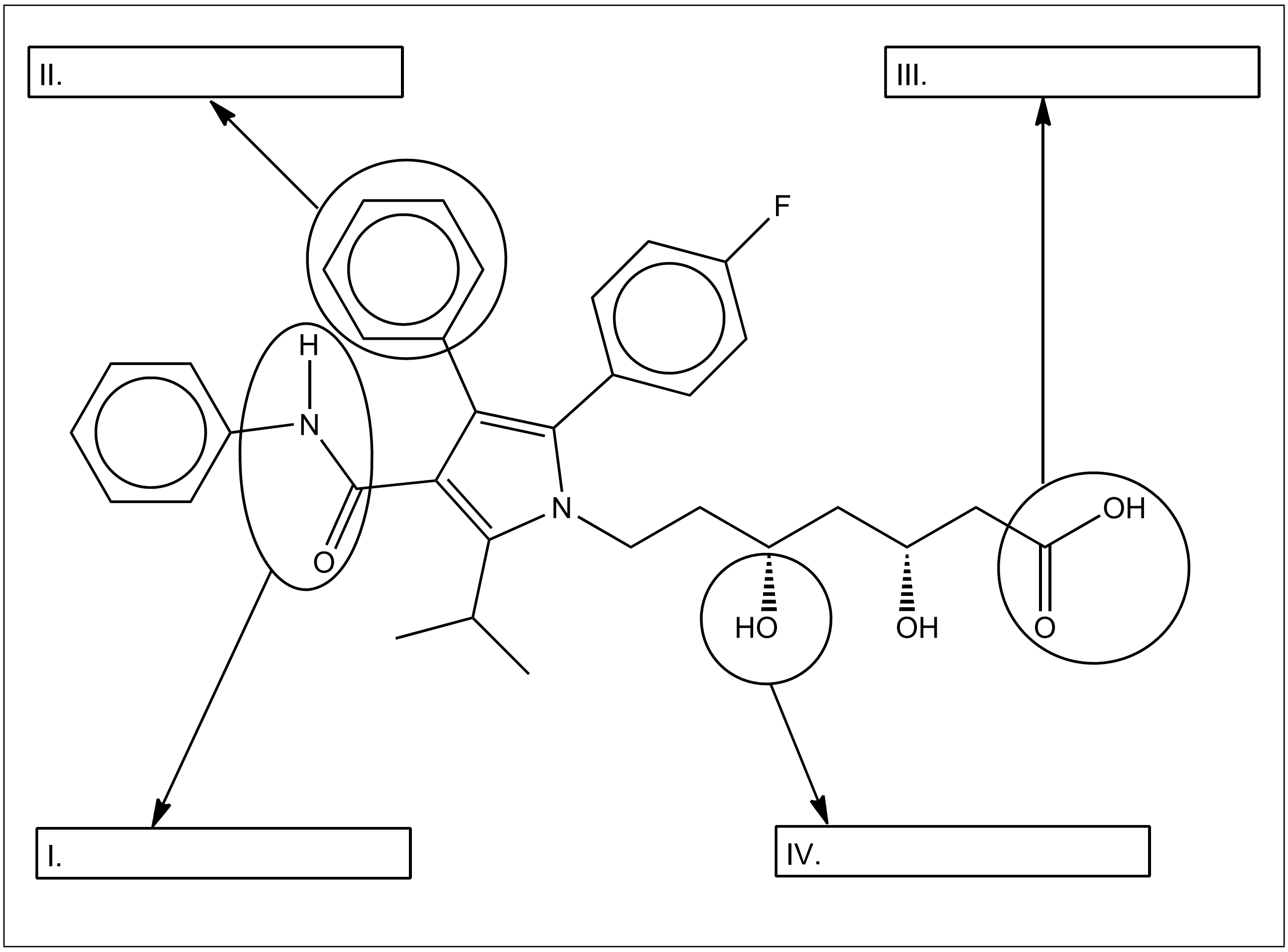
7. The biopharmaceutical industry is now a global contributor to the world economy.

(a) Atorvastatin, a drug used to lower cholesterol, recently gained attention from the global media.

Atorvastatin has the structure shown below.



Identify the **four** functional groups, I, II, III and IV. *[2]*

(This question continues on the following page)

(Question 7 continued)

(b) Bute, a painkiller used on horses, has caused widespread concern recently because analytical tests showed that it entered the food chain through horse meat labelled as beef. The drug is suspected of causing cancer.

(i) Analysis of a sample of bute carried out in a food safety laboratory gave the following elemental percentage compositions by mass:

Element	**Percentage**
C	73.99
H	6.55
N	9.09
O	Remainder

Calculate the empirical formula of bute, showing your working. *[3]*

. . . .

. . . .

. . . .

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(ii) The molar mass, M, of bute, is $308.37\,g\,mol^{-1}$. Calculate the molecular formula. *[1]*

. . . .

. . . .

. . . .

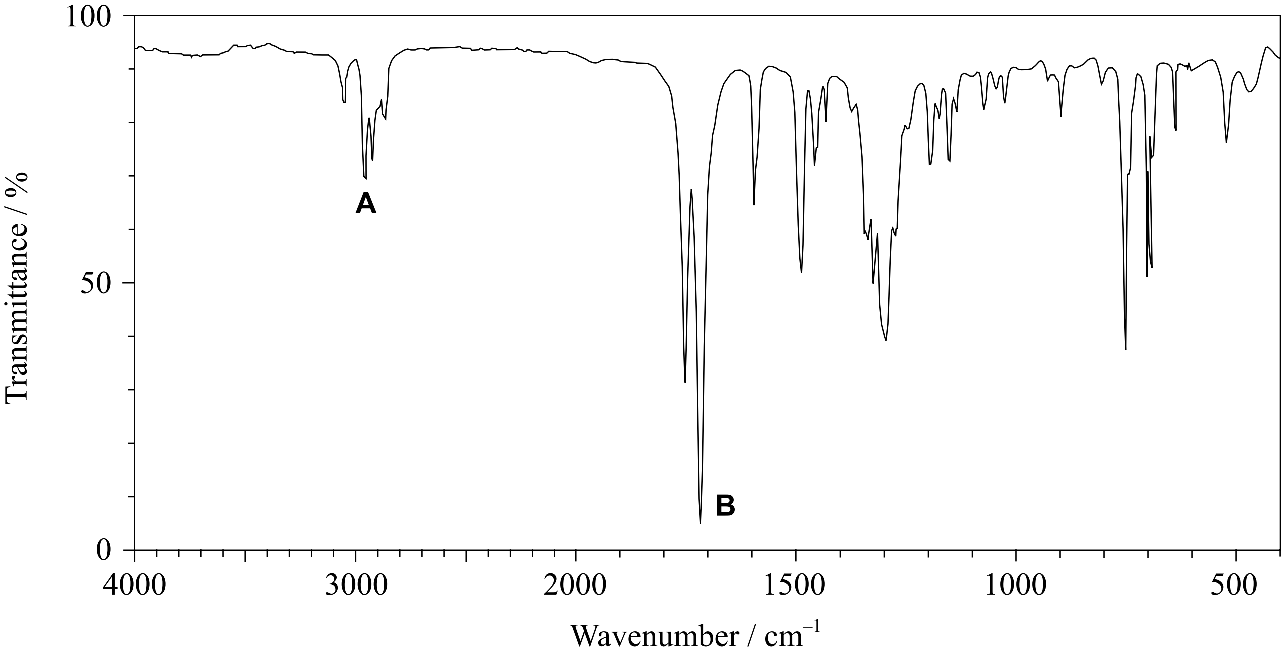
(This question continues on the following page)

(Question 7 continued)

(iii) Deduce the degree of unsaturation (index of hydrogen deficiency – IHD) of bute. *[1]*

. . . .
. . . .
. . . .

(iv) The infrared (IR) spectrum of bute is shown below.



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

Using information from section 26 of the data booklet, identify the bonds corresponding to **A** and **B**. *[1]*

A: . . . .

B: . . . .

(This question continues on the following page)

(Question 7 continued)

(v) Based on analysis of the IR spectrum, predict, with an explanation, one bond containing oxygen and one bond containing nitrogen that could **not** be present in the structure. *[2]*

Bond containing oxygen not present in structure:

. . . .

Bond containing nitrogen not present in structure:

. . . .

Explanation:

. . . .

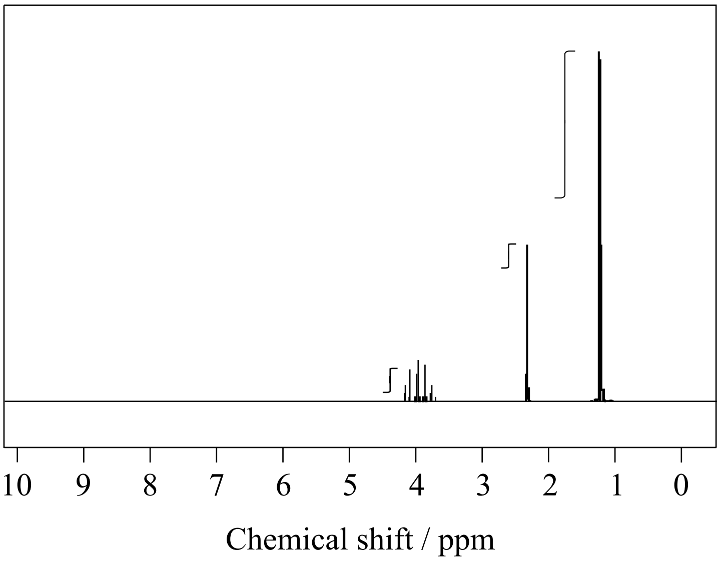
. . . .

. . . .

(This question continues on the following page)

(Question 7 continued)

(c) An alcohol, **X**, of molecular formula C_3H_8O, used as a disinfectant in hospitals, has the following ^1H NMR spectrum:



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

The three peaks in the ^1H NMR spectrum of **X** have chemical shift values centred at $\delta =$ 4.0, 2.3 and 1.2 ppm.

(i) From the integration trace, estimate the ratio of hydrogen atoms in different chemical environments. *[1]*

. . . .

. . . .

(ii) Deduce the full structural formula of **X**. *[1]*

(This question continues on the following page)

(Question 7 continued)

(iii) **Y** is an isomer of **X** containing a different functional group. State the condensed structural formula of **Y**. *[1]*

. . . .
. . . .

(iv) Compare and contrast the expected mass spectra of **X** and **Y** using section 28 of the data booklet. *[2]*

One similarity:

. . . .
. . . .
. . . .

One difference:

. . . .
. . . .
. . . .

(This question continues on the following page)

(Question 7 continued)

(v) Both **X** and **Y** are soluble in water. Deduce whether or not both **X** and **Y** show hydrogen bonding with water molecules, representing any hydrogen bonding present by means of a diagram. *[2]*

. . . .

. . . .

(This question continues on the following page)

(Question 7 continued)

(d) The two isomers of $[Pt(NH_3)_2Cl_2]$ are crystalline. One of the isomers is widely used as a drug in the treatment of cancer.

(i) Draw both isomers of the complex. *[1]*

(ii) Explain the polarity of each isomer, using a diagram for each isomer to support your answer. *[2]*

. . . .

. . . .

(iii) State a suitable method (other than looking at dipole moments) to distinguish between the two isomers. *[1]*

. . . .

(This question continues on the following page)

(Question 7 continued)

(iv) Compare and contrast the bonding types formed by nitrogen in $[Pt(NH_3)_2Cl_2]$. *[2]*

Similarity:

. . . .

. . . .

Difference:

. . . .

. . . .

(v) Deduce all of the intermolecular forces between molecules of ammonia. *[2]*

. . . .

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. . . .

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will not be marked.

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MARKSCHEME

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Paper 2

17 pages

Subject Details: Chemistry HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions. Maximum total = **[95 marks]**.

1. Each row in the “Question” column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the “Total” column.

3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.

5. An alternative wording is indicated in the “Answers” column by a slash (**/**). Either wording can be accepted.

6. An alternative answer is indicated in the “Answers” column by “***OR***” on the line between the alternatives. Either answer can be accepted.

7. Words in angled brackets **‹ ›** in the “Answers” column are not necessary to gain the mark.

8. Words that are <u>underlined</u> are essential for the mark.

9. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.

10. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the “Notes” column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "ECF acceptable" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

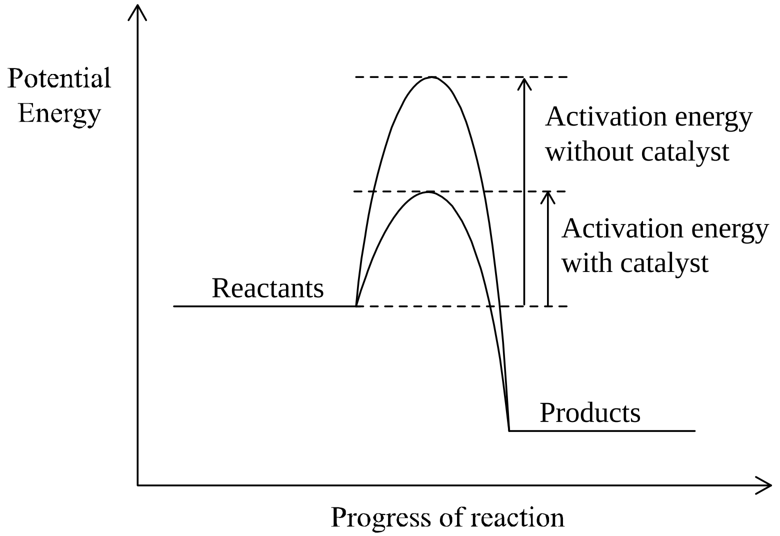
14. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column, similarly, if the formula is specifically asked for, unless directed otherwise in the "Notes" column do not award a mark for a correct name.

15. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

16. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

Question			Answers	Notes	Total
1.	**a**	**i**	‹$(22.05+22.15)(0.5)=$› 22.10 ‹cm^3› ✓		**1**
	a	**ii**	$\left\langle \frac{22.10\times 0.100}{1000} = \right\rangle 2.21\times 10^{-3}$ / 0.00221 ‹mol› ✓		**1**
	a	**iii**	$\left\langle \frac{0.5\times 2.21\times 10^{-3}\times 1000}{25.00} = \right\rangle 4.42\times 10^{-2}$ / 0.0442 ‹$mol\,dm^{-3}$› ✓		**1**
	a	**iv**	‹$4.42\times 10^{-2}\times 10=$› 4.42×10^{-1} / 0.442 ‹$mol\,dm^{-3}$› ✓		**1**
	b	**i**	*NaClO*: +1 ‹for chlorine› **and** *I_2*: 0 ‹for iodine› ✓		**1**
	b	**ii**	ClO^- since chlorine reduced/gains electrons ***OR*** ClO^- since oxidation state of chlorine changes from +1 to –1/decreases ***OR*** ClO^- since it loses oxygen / causes iodide to be oxidized ✓		**1**
	b	**iii**	produces chlorine ‹gas›/Cl_2 ‹on reaction with ClO^-› which is toxic ✓	*OWTTE*	**1**
	b	**iv**	oxidation states are not real ***OR*** oxidation states are just used for electron book-keeping purposes ✓ average oxidation state of sulfur calculated to be +2 ✓ but the two sulfurs are bonded differently/in different environments in thiosulfate so have different oxidation states ✓	*OWTTE*	**2 max**

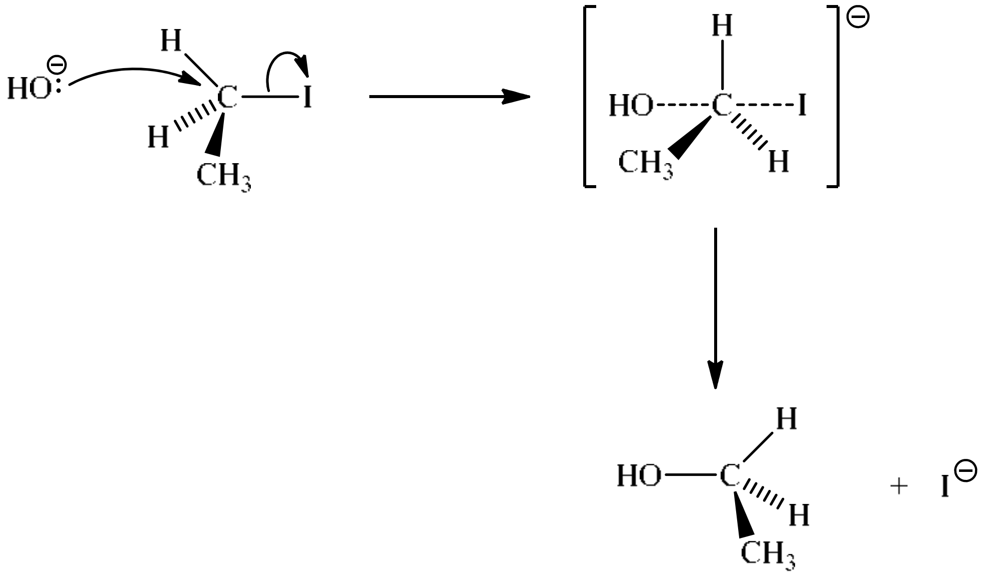
Question			Answers	Notes	Total
	c		*Valid:* addition of oxygen signifies an oxidation reaction so C is oxidized ***OR*** loss of hydrogen signifies an oxidation reaction so C is oxidized ***OR*** oxidation state of C changes from –4 to +4/increases ✓ *Not valid:* loss of electrons might suggest formation of ionic product but not valid since CO_2 is covalent ***OR*** loss of electrons might suggest formation of ionic product but not valid since reaction only involves neutral molecules ✓	*OWTTE*	**2**
	d	**i**	$[Ne]3s^2 3p^4$ ✓	*Electrons must be given as superscript.*	**1**
	d	**ii**	[↑↓] $1s^2$ [↑↓] $2s^2$ [↑↓][↑↓][↑↓] $2p^6$ [↑↓] $3s^2$ [↑↓][↑][↑] $3p^4$ ✓		**1**

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Notes</th><th>Total</th></tr>
<tr><td>2.</td><td>a</td><td></td><td>radical / unpaired electron ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>b</td><td></td><td><table><tr><th>Change</th><th>Shift</th><th>Reason</th></tr><tr><td>Increase in temperature</td><td>LHS</td><td>since ‹forward› exothermic reaction/ $\Delta H < 0$ ✓</td></tr><tr><td>Increase in pressure</td><td>RHS</td><td>since fewer ‹gaseous› molecules on RHS ✓</td></tr><tr><td>Addition of a catalyst to the mixture</td><td>No change</td><td>since affects rate of forward and reverse reactions equally ✓</td></tr></table></td><td></td><td>3</td></tr>
<tr><td></td><td>c</td><td></td><td>

correct positions of reactants and products ✓
correct profile with labels showing activation energy with and without a catalyst ✓</td><td></td><td>2</td></tr>
</table>

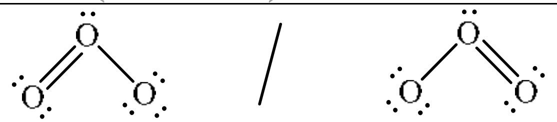
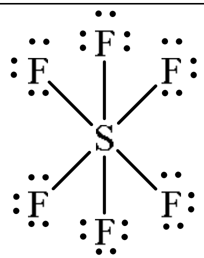
Question			Answers	Notes	Total
	d		$2NO_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$ ✓	*Ignore state symbols.*	**1**
	e		ionic radius of nitrogen is 146 pm/146×10^{-12} m which is greater than atomic radius which is 71 pm/71×10^{-12} m due to increased repulsion between electrons ✓	*Values must be given to score mark.*	**1**

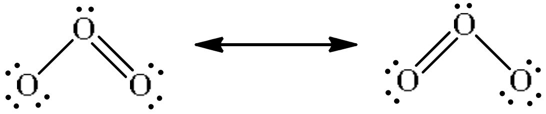
3.	**a**		$HCOO^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + HCOOH(aq)$ ✓	*Equilibrium sign must be given for mark.*	**1**
	b		$K_a = 1.8\times10^{-4}$ ✓		**1**
	c		$K_b = \left\langle \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{1.8\times10^{-4}} = \right\rangle 5.6\times10^{-11}$ ✓		**1**
	d		$K_b = \frac{x^2}{0.12} = 5.6\times10^{-11}$ ✓ $[OH^-(aq)] = 2.6\times10^{-6} \langle mol\,dm^{-3} \rangle$ ✓ *Assumption:* $0.12 - x \sim 0.12$ ✓	*Award **[2]** for correct final answer of $[OH^-(aq)]$.* *Accept any other reasonable assumption.*	**3**
	e		$pOH = \langle -\log(2.6\times10^{-6}) = \rangle 5.59$ ✓ $pH = \langle 14.00 - 5.59 = \rangle 8.41$ ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
4.	**a**				**4**
			curly arrow going from lone pair/negative charge on O in HO^- to C ✓	*Do not allow curly arrow originating on H in* HO^-	
			curly arrow showing I leaving ✓	*Accept curly arrow going from bond between C and I to I in 1-iodoethane or in the transition state.* *Do not allow arrow originating from C to C–I bond.*	
			representation of transition state showing negative charge, square brackets and partial bonds at 180° to each other ✓	*Do not award M3 if OH---C bond is represented.*	
			formation of organic product CH_3CH_2OH **and** I^- ✓	*Inversion of configuration must be shown to score M4.*	
	b		*Rate expression:* rate = $k[OH^-][CH_3CH_2I]$ ✓ *Molecularity of RDS:* bimolecular ✓		**2**

Question			Answers	Notes	Total
	c		*S_N2:* polar, protic solvents decrease nucleophilic reactivity due to hydrogen bonding ***OR*** polar, protic solvents have a cage of solvent molecules surrounding anionic nucleophile resulting in increased stabilization ‹so are slower› ***OR*** polar, aprotic solvents have no hydrogen bonding so S_N2 reactions are favoured since nucleophiles do not solvate effectively so have an enhanced/pronounced effect on nucleophilicity of anionic nucleophiles ‹so are faster› ✓ *S_N1:* polar, protic solvents favour S_N1 reactions since the carbocation ‹intermediate› is solvated by ion-dipole interactions by the polar solvent ✓		**2**
	d		DMF since aprotic solvent so favours S_N2 ✓		**1**
	e		*A* is indicative of frequency of collisions **and** probability that collisions have proper orientations ✓		**1**
	f		$k = \left\langle \exp\left[\frac{(-87.0\times1000)}{(8.31\times298)} + \ln(2.10\times10^{11})\right] = \right\rangle 1.2\times10^{-4}$ ✓ S_N2 implies second-order so $mol^{-1}\ dm^3\ s^{-1}$ ✓		**2**

Question			Answers	Notes	Total
5.	**a**		only water/H_2O produced ‹so non-polluting› ✓		**1**
	b		*Bond breaking*: $(1)(H–H)+(4)(C–H)+(1)(C{=}C)$ ***OR*** $(1)(436)+(4)(414)+(1)(614) = 2706$ ‹$kJ\ mol^{-1}$› ✓ *Bond formation*: $(6)(C–H)+(1)(C–C)$ ***OR*** $(6)(414)+(1)(346)=2830$ ‹$kJ\ mol^{-1}$› ✓ ‹$+2706-2830$› $=-124$ ‹$kJ\ mol^{-1}$› ✓	*Award **[2 max]** for +124 ‹kJ mol^{-1}›.* *Award **[3]** for correct final answer.*	**3**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>6.</td><td>a</td><td>i</td><td>
<table>
<tr><th></th><th>Lewis (electron dot) structure</th></tr>
<tr><td>Ozone</td><td> ✓</td></tr>
<tr><td>Sulfur hexafluoride</td><td> ✓</td></tr>
</table>
</td><td>Lines, x’s or dots may be used to represent electron pairs.
Charges may be included in Lewis structures of ozone but are not required.</td><td>2</td></tr>
<tr><td></td><td>a</td><td>ii</td><td>
<table>
<tr><th></th><th>Electron domain geometry</th><th>Molecular geometry</th></tr>
<tr><td>Ozone</td><td>trigonal/triangular planar</td><td>v-shaped/bent/angular ✓</td></tr>
<tr><td>Sulfur hexafluoride</td><td>octahedral/square bipyramidal</td><td>octahedral/square bipyramidal ✓</td></tr>
</table>
</td><td>Award [1 max] for either both electron domain geometries correct OR for either both molecular geometries correct.</td><td>2</td></tr>
<tr><td></td><td>a</td><td>iii</td><td>sulfur hexafluoride/SF_6 ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>a</td><td>iv</td><td>Ozone: Accept any angle greater than 115° but less than 120°
and
Sulfur hexafluoride: 90° (and 180°) ✓</td><td>Experimental value of bond angle in O_3 is 117°.</td><td>1</td></tr>
</table>

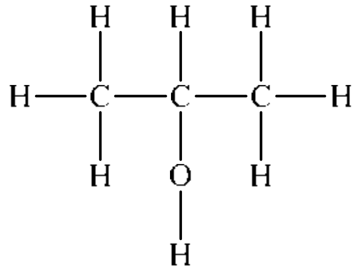
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>6.</td><td>a</td><td>v</td><td> ✓</td><td>Double-headed arrow not necessary for mark.
Lines, x's or dots may be used to represent electron pairs.</td><td>1</td></tr>
<tr><td></td><td>b</td><td>i</td><td><table>
<tr><th></th><th>Lewis (electron dot) structure</th><th>FC of O on LHS</th><th>FC of central N</th><th>FC of N on RHS</th></tr>
<tr><td>A</td><td>$:\ddot{O}=N=\ddot{N}:$</td><td>0</td><td>+1</td><td>–1</td></tr>
<tr><td>B</td><td>$:\ddot{\underset{..}{O}}-N\equiv N:$</td><td>–1</td><td>+1</td><td>0</td></tr>
<tr><td>C</td><td>$:O\equiv N-\ddot{\underset{..}{N}}:$</td><td>+1</td><td>+1</td><td>–2</td></tr>
</table></td><td>Award [2] for all nine FCs correct, [1] for six to eight FCs correct.</td><td>2</td></tr>
<tr><td></td><td>b</td><td>ii</td><td>smallest FC difference for A or B, so either is preferred ✓

however B is preferred as oxygen is more electronegative than nitrogen, even though FC per se ignores electronegativity ✓</td><td>Reason required for M1.

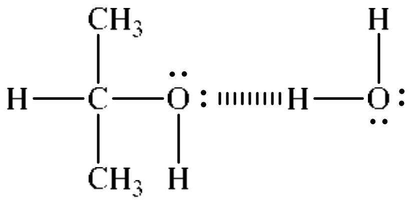
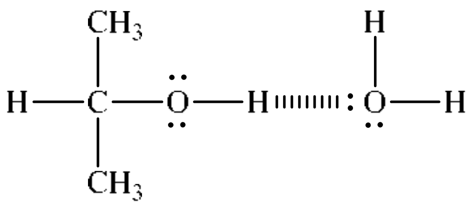
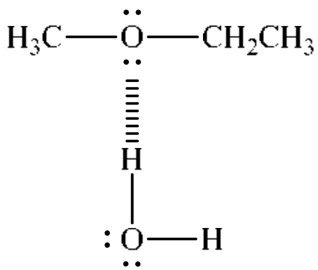
OWTTE</td><td>2</td></tr>
<tr><td></td><td>c</td><td>i</td><td>$CH_4(g) + 5O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + 2O_3(g)$ ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>c</td><td>ii</td><td>$\Delta H^{\ominus} = \langle [(-393.5) + (2)(-241.8) + (2)(+142.3)] - [(-74.0)] = \rangle -660.8 \langle kJ\,mol^{-1} \rangle$ ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>c</td><td>iii</td><td>standard enthalpy change of formation/ $\Delta H_f^{\ominus}$ of an element ‹in most stable form› is always zero ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>c</td><td>iv</td><td>$\Delta S^{\ominus} = \langle [(+213.8) + (2)(+188.8) + (2)(+237.6)] - [(+186) + (5)(+205.0)] = \rangle$
$-144.4 \langle J\,K^{-1}\,mol^{-1} \rangle$ ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>c</td><td>v</td><td>$\Delta G^{\ominus} = \left\langle \Delta H^{\ominus} - T\Delta S^{\ominus} = (-660.8) - (298)\left(\frac{-144.4}{1000}\right) = \right\rangle -617.8 \langle kJ\,mol^{-1} \rangle$ ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>c</td><td>vi</td><td>spontaneous since negative $\Delta G^{\ominus}$ ✓</td><td></td><td>1</td></tr>
</table>

Question			Answers	Notes	Total
6.	**d**	**i**	O_2 has a double bond ✓ O_3 has intermediate bonds between double and single bonds ***OR*** O_3 has a bond order of 1½ ✓ bond in O_2 is stronger therefore **I** needs more energy ✓	*Do not award mark for **I** on its own with no justification.*	**3**
	d	**ii**	C–Cl ‹bond› breaks since weakest bond ✓ $CCl_2F_2 \xrightarrow{\langle hv \rangle} \bullet CClF_2 + Cl\bullet$ ✓ $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ ✓ $ClO\bullet + O\bullet \rightarrow O_2 + Cl\bullet$ ✓ $ClO\bullet + O_3 \rightarrow Cl\bullet + 2O_2$ ✓	*Allow representation of radicals without • as long as consistent throughout.*	**5**

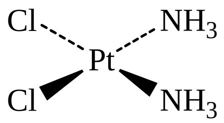
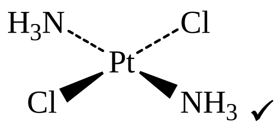
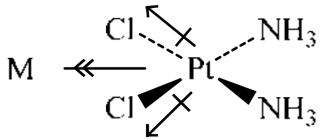
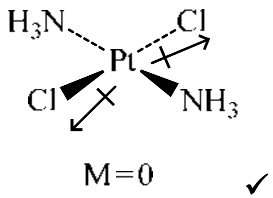
Question			Answers	Notes	Total
7.	a		*I:* carboxamide ✓ *II:* phenyl ✓ *III:* carboxyl / carboxy ✓ *IV:* hydroxyl ✓	*Award **[2]** for all four correct, **[1]** for two or three correct.* *Do not allow benzene.* *Do not allow carboxylic/alkanoic acid.* *Do not allow alcohol or hydroxide.*	**2 max**
	b	i	$n_C : \left\langle \frac{73.99}{12.01} \right\rangle = 6.161\,(\text{mol})$ **and** $n_H : \left\langle \frac{6.55}{1.01} \right\rangle = 6.49\,(\text{mol})$ **and** $n_N : \left\langle \frac{9.09}{14.01} \right\rangle = 0.649\,(\text{mol})$ **and** $n_O : \left\langle \frac{10.37}{16.00} \right\rangle = 0.6481\,(\text{mol})$ ✓ $n_C : n_H : n_N : n_O = 9.5 : 10 : 1 : 1$ ✓ *Empirical formula*: $C_{19}H_{20}N_2O_2$ ✓	*Award **[2 max]** for correct final answer without working.*	**3**
	b	ii	$C_{19}H_{20}N_2O_2$ ✓		**1**
	b	iii	⟨(0.5)(40 – 20 + 4 – 2) = ⟩11 ✓		**1**
	b	iv	*A:* C–H **and** *B:* C=O ✓		**1**
	b	v	O–H **and** N–H ✓ frequencies/stretches due to O–H and N–H occur above 3200 ‹cm^{-1}› which are not present in IR of *bute* ✓		**2**
	c	i	1:1:6 ✓		**1**

Question			Answers	Notes	Total
7.	**c**	**ii**	 ✓		**1**
	c	**iii**	$CH_3OCH_2CH_3$ ✓		**1**
	c	**iv**	*Similarity:* both have fragment corresponding to $(M_r - 15)^+$ / $m/z = 45$ ✓ *Difference:* **X** has fragment corresponding to $(M_r - 17)^+$ / $m/z = 43$ ***OR*** **X** has fragment corresponding to $(M_r - 43)^+$ / $m/z = 17$ ***OR*** **Y** has fragment corresponding to $(M_r - 31)^+$ / $m/z = 29$ ***OR*** **Y** has fragment corresponding to $(M_r - 29)^+$ / $m/z = 31$ ✓	*Allow "both have same molecular ion peak/M^+ / both have m/z = 60". However in practice the molecular ion peak is of low abundance and difficult to observe for propan-2-ol.*	**2**

(Question 7 continued)

Question			Answers	Notes	Total
	c	**v**	both **X** and **Y** will exhibit hydrogen bonding with water molecules ✓ diagrams showing hydrogen bonding ✓ X:  **OR**  Y: 		**2**

(Question 7 continued)

Question			Answers	Notes	Total
7.	**d**	**i**	 Cisplatin **and**  Transplatin ✓	*Names of complexes are not required.* *Complexes may be drawn without tapered bonds.*	**1**
	d	**ii**	 Cisplatin **and**  Transplatin ✓ *Cis:* polar **and** *trans:* non-polar ✓		**2**
	d	**iii**	X-ray crystallography ✓	*Accept NMR spectroscopy.*	**1**
	d	**iv**	*Similarity:* both involve shared pair of electrons / both are covalent ✓ *Difference:* *Pt–N:* pair of electrons comes from nitrogen / coordinate bond **and** *N–H:* one electron comes from each bonded atom ✓		**2**
	d	**v**	London / dispersion / instantaneous induced dipole-induced dipole ✓ dipole-dipole ✓ hydrogen bonding ✓	*Award* **[2]** *for all three correct,* **[1]** *for any two correct.*	**2 max**

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CHEMISTRY
HIGHER LEVEL
PAPER 3

Candidate session number

SPECIMEN PAPER

Examination code

1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer all of the questions from one of the options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the *Chemistry data booklet* is required for this paper.
- The maximum mark for this examination paper is *[45 marks]*.

Option	**Questions**
Option A — Materials	3 – 7
Option B — Biochemistry	8 – 12
Option C — Energy	13 – 16
Option D — Medicinal chemistry	17 – 21

SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

1. Compounds used to generate cooling in refrigerators and air-conditioning systems are known as refrigerants. A refrigerant undergoes a reversible change of state involving vaporization and condensation. The search for suitable refrigerants has occupied chemists for approximately 200 years.

Previously, the most popular refrigerants were chlorofluorocarbons (CFCs), but these have been replaced first by hydrochlorofluorocarbons (HCFCs) and more recently by hydrofluorocarbons (HFCs).

Some data on examples of these three classes of refrigerants are shown below.

Class	**Compound**	**ODP**[1]	**GWP**[2] **over 100 years**	ΔH_{vap}[3] **/ kJ mol**$^{-1}$	**Atmospheric lifetime / years**
CFC	CCl_3F	1.0	4000	24.8	45
CFC	CCl_2F_2	1.0	8500	20.0	102
HCFC	$CHCl_2CF_3$	0.02	90	26.0	1
HCFC	$CHClF_2$	0.05	1810	20.2	12
HFC	CH_2FCF_3	0	1100	–	–
HFC	CHF_2CF_3	0	3500	30.0	32

[1] ODP: The ozone depletion potential (ODP) is a relative measure of the amount of degradation to the ozone layer caused by the compound. It is compared with the same mass of CCl_3F, which has an ODP of 1.0.

[2] GWP: The global warming potential (GWP) is a relative measure of the total contribution of the compound to global warming over the specified time period. It is compared with the same mass of CO_2, which has a GWP of 1.0.

[3] ΔH_{vap}: Defined as the energy required to change one mole of the compound from a liquid to a gas.

(a) (i) Explain why the values for ODP and GWP have no units. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(ii) By making reference to the chemical formulas and ODP values of the compounds, comment on the hypothesis that chlorine is responsible for ozone depletion. *[1]*

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(b) Use data from the table to interpret the relationship between the atmospheric lifetime of a gas and its GWP. *[2]*

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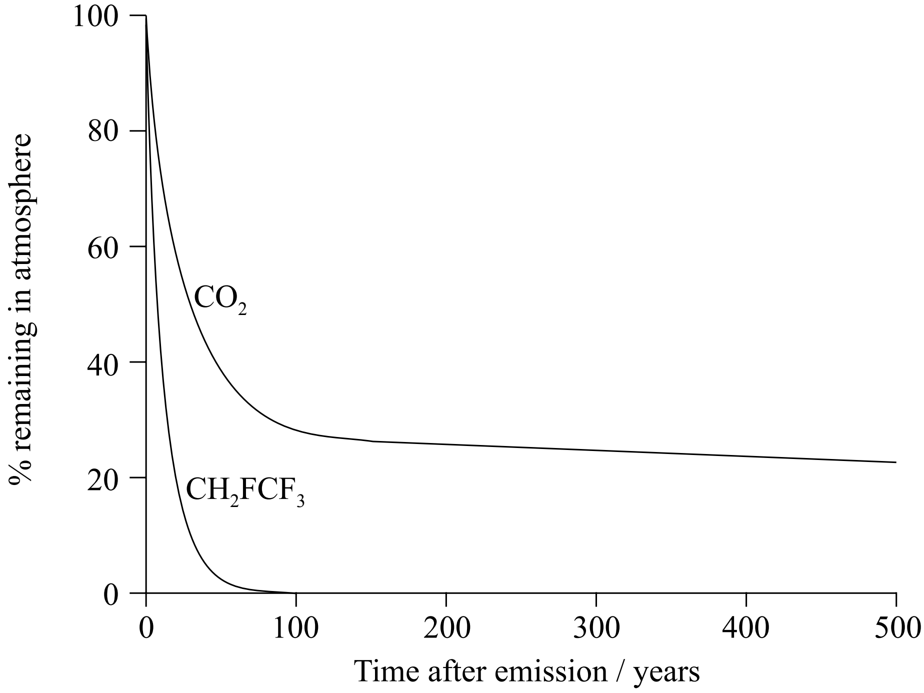
(This question continues on the following page)

(Question 1 continued)

(c) The graph shows the change in levels with time of equal masses of CO_2 and CH_2FCF_3 introduced into the atmosphere.



(i) Apply IUPAC rules to state the name of CH_2FCF_3. *[1]*

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(ii) The $\Delta H_{\text{vaporization}}$ for CH_2FCF_3 is $217\,kJ\,kg^{-1}$. Calculate the value of the enthalpy change for the condensation of one mole of CH_2FCF_3. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(iii) With reference to the graph on page 4, comment on the atmospheric lifetime of CO_2 relative to CH_2FCF_3, and on the likely influence of this on climate change. *[2]*

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2. Thomas wants to determine the empirical formula of red-brown copper oxide. The method he chooses is to convert a known amount of copper(II) sulfate into this oxide. The steps of his procedure are:

- Make 100 cm^3 of a 1 mol dm^{-3} solution using hydrated copper(II) sulfate crystals.
- React a known volume of this solution with alkaline glucose in order to convert it to red-brown copper oxide.
- Separate the precipitated oxide and find its mass.

(a) Thomas calculates that he needs $0.1 \times [1 \times 63.55 + 1 \times 32.07 + 4 \times 16.00] = 15.962 \pm 0.001$ g of the copper(II) sulfate to make the solution. Outline the major error in his calculation. *[1]*

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(b) He now adds 100 ± 1 cm^3 of water from a measuring/graduated cylinder and dissolves the copper(II) sulfate crystals. A friend tells him that for making standard solutions it is better to use a volumetric flask rather than adding water from a measuring cylinder. Suggest **two** reasons why a volumetric flask is better. *[2]*

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(c) Thomas now heats 25 cm^3 of the solution with excess alkaline glucose to convert it to a suspension of red-brown copper oxide. Describe how he can obtain the pure, dry solid product. *[2]*

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(This question continues on the following page)

(Question 2 continued)

(d) Using the same chemical reactions, suggest how Thomas' method to determine the mass of red-brown copper oxide that could be obtained from a known mass of copper(II) sulfate crystals might be simplified to produce more precise results. *[1]*

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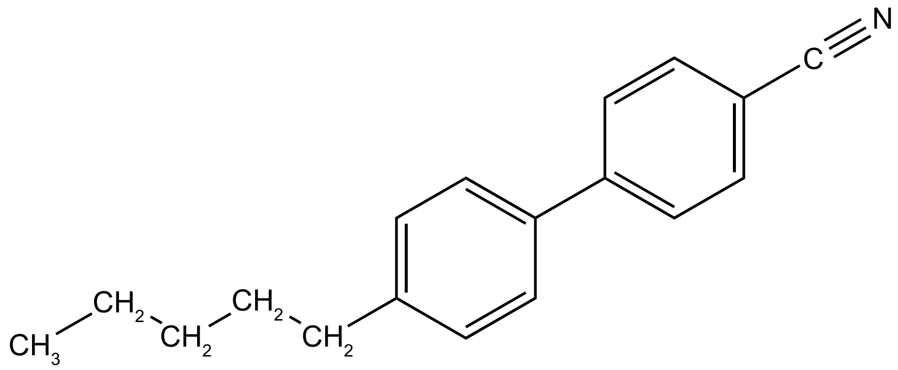
SECTION B

*Answer **all** of the questions from **one** of the options. Write your answers in the boxes provided.*

Option A — Materials

3. (a) The molecule shown below is frequently used in liquid-crystal displays (LCDs).



Identify a physical characteristic of this molecule that allows it to exist in a liquid-crystal state. *[1]*

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(b) (i) Describe the chemical vapour deposition (CVD) method for the production of carbon nanotubes. *[2]*

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(ii) Many modern catalysts use carbon nanotubes as a support for the active material. State the major advantage of using carbon nanotubes. *[1]*

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(Option A continues on the following page)

(Option A continued)

4. Different metal oxides are widely used in the production of ceramic materials and their function is closely linked to the type of bonding present in the compound.

(a) Both magnesium oxide and cobalt(II) oxide are incorporated into ceramics. Use section 8 of the data booklet to calculate values to complete the table below. *[2]*

Compound	**Magnesium oxide**	**Cobalt(II) oxide**
Electronegativity difference	. . . .	. . . .
Average electronegativity	. . . .	. . . .

(b) Predict the bond type and percentage covalent character of each oxide, using section 29 of the data booklet. *[2]*

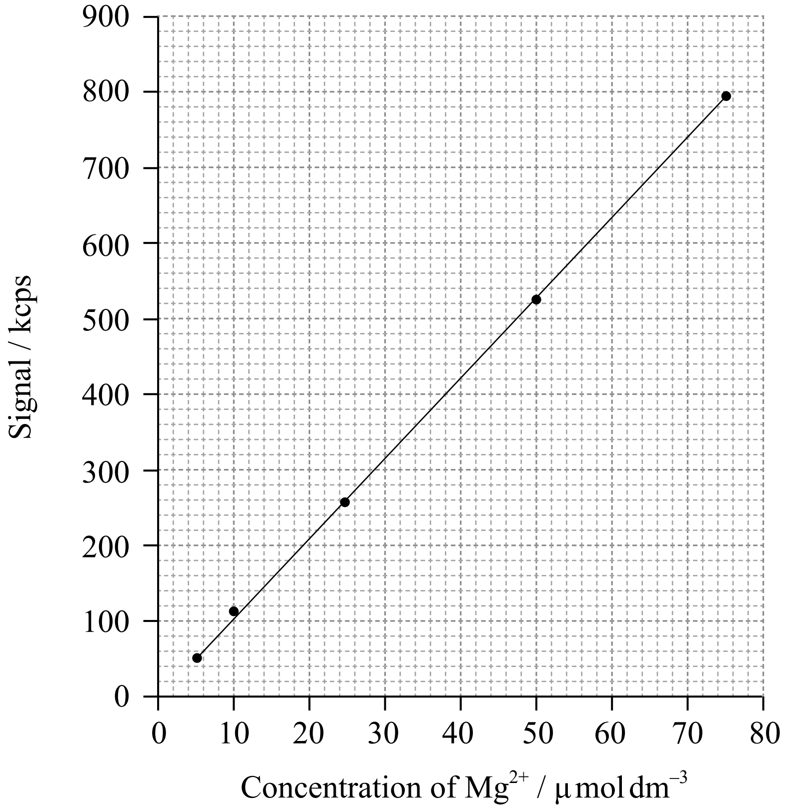
Compound	**Magnesium oxide**	**Cobalt(II) oxide**
Bond type	. . . .	. . . .
% covalent character	. . . .	. . . .

(Option A continues on the following page)

(Option A continued)

5. Magnesium is an essential component of chlorophyll and traces of it can be found in various fluids from plants. Its concentration may be estimated using inductively coupled plasma optical emission spectroscopy (ICP-OES).

(a) An ICP-OES calibration curve for magnesium is shown in the graph below.



(i) Determine the mass of magnesium ions present in 250 cm^3 of a solution with a concentration of 10 μmol dm^{-3}. *[2]*

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(Option A continues on the following page)

(Option A, question 5 continued)

(ii) Two solutions gave count rates of 627 kcps and 12 kcps respectively. Justify which solution could be more satisfactorily analysed using this calibration graph. *[1]*

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(b) Magnesium ion concentrations could also be determined by precipitation as magnesium hydroxide. The solubility product of magnesium hydroxide is 1.20×10^{-11} at 298 K. A saturated solution of magnesium hydroxide is formed, at 298 K, in a solution with a hydroxide ion concentration of $2.00\,mol\,dm^{-3}$. Calculate the magnesium ion concentration. *[3]*

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(Option A continues on the following page)

(Option A continued)

6. Plastics, such as PVC and melamine, are widely used in modern society.

(a) PVC is thermoplastic, whereas melamine is thermosetting. State one other way in which scientists have tried to classify plastics, and outline why the classification you have chosen is useful. *[2]*

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(b) It was almost a century after the discovery of PVC before Waldo Semon turned it into a useful plastic by adding plasticizers. State and explain the effect plasticizers have on the properties of PVC. *[2]*

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(c) Justify why, in terms of atom economy, the polymerization of PVC could be considered "green chemistry". *[1]*

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(Option A continues on the following page)

(Option A, question 6 continued)

(d) In spite of the conclusion in part (c), many consider that PVC is harmful to the environment. Identify **one** specific toxic chemical released by the combustion of PVC. *[1]*

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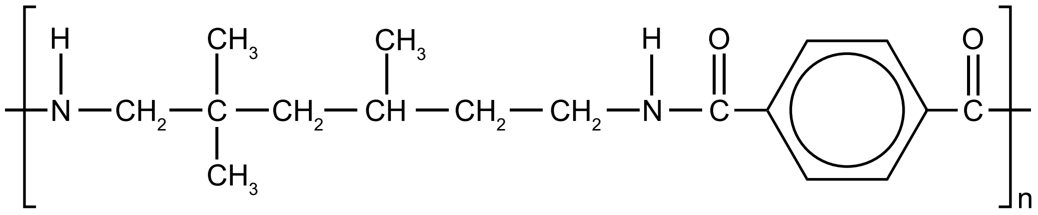
(e) The formula below shows the repeating unit of a polymer marketed as Trogamid®.



Deduce both the class of polymer to which this belongs **and** the structural formulas of the monomers used to produce it. *[2]*

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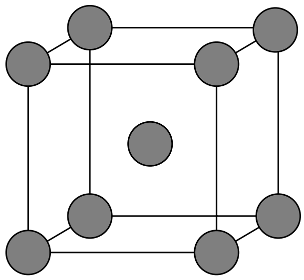
(Option A continues on the following page)

(Option A continued)

7. Superconductors are now widely used in devices such as MRI scanners and MagLev trains. Many superconductors involve the use of niobium.

(a) Niobium is most commonly found in a crystalline form with the unit cell shown below.



Classify the crystal structure, the coordination number of the atoms and the number of atoms to which the unit cell is equivalent. *[3]*

Crystal structure:

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Coordination number:

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Number of atoms:

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(b) X-ray diffraction shows that the length of the side of the unit cell is 0.314 nm. Use this, along with data from part (a), to determine the density, in $kg\,m^{-3}$, of niobium. *[3]*

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(Option A continues on the following page)

(Option A, question 7 continued)

(c) According to Bardeen-Cooper-Schrieffer (BCS) theory, Cooper pairs account for Type 1 superconductivity. Describe how Cooper pairs are formed and the role of the positive ion lattice in this. *[2]*

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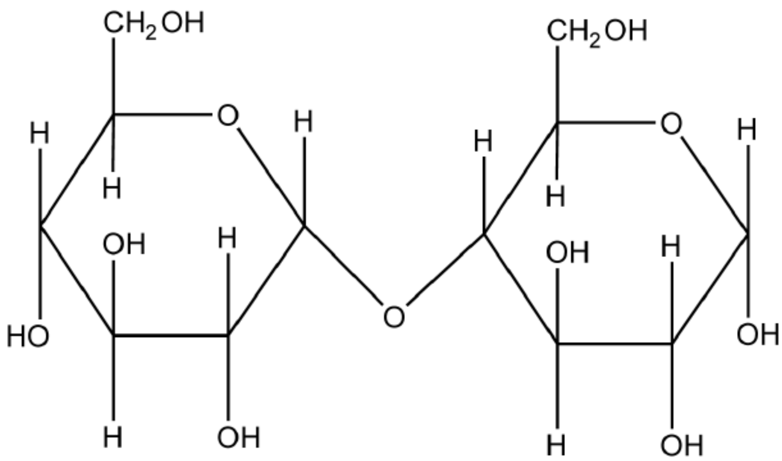
End of Option A

Option B — Biochemistry

8. The diagram below shows the structure of a disaccharide called maltose.



(a) Identify on the diagram one primary alcohol group by marking I on the oxygen, **and** one secondary alcohol group by marking II on the oxygen. *[1]*

(b) (i) Formulate an equation, using molecular formulas, to show the conversion of this molecule into its monomers. *[1]*

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(ii) Identify the type of metabolic process shown in part (b)(i). *[1]*

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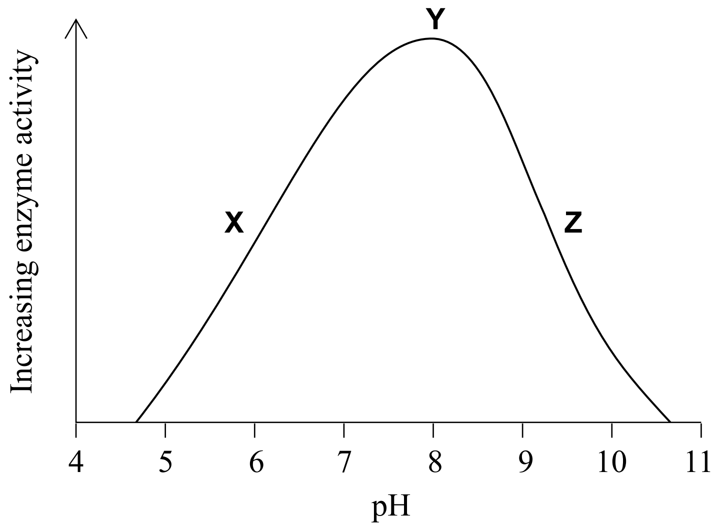
(Option B continues on the following page)

(Option B, question 8 continued)

(c) The reaction in part (b) is catalysed by the enzyme maltase. Experiments were carried out to investigate the rate of breakdown of maltose in the presence of maltase over a range of pH values from 4 to 11. The results are shown below.



Describe how the activity of the enzyme changes with pH, including in your answer specific reference to how the pH is affecting the enzyme at **X**, **Y** and **Z**. *[3]*

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(Option B continues on the following page)

(Option B, question 8 continued)

(d) The experiments described in part (c) use a range of buffer solutions. A student needed to make 1.00 dm^3 of pH 5.00 buffer solution starting with 0.10 $mol\,dm^{-3}$ butanoic acid solution and solid sodium butanoate. The molar mass of sodium butanoate is 110.01 $g\,mol^{-1}$.

Use information from sections 1 and 21 of the data booklet to determine how much of each component the student should mix together. Assume no volume change occurs on mixing. Show all your working. *[3]*

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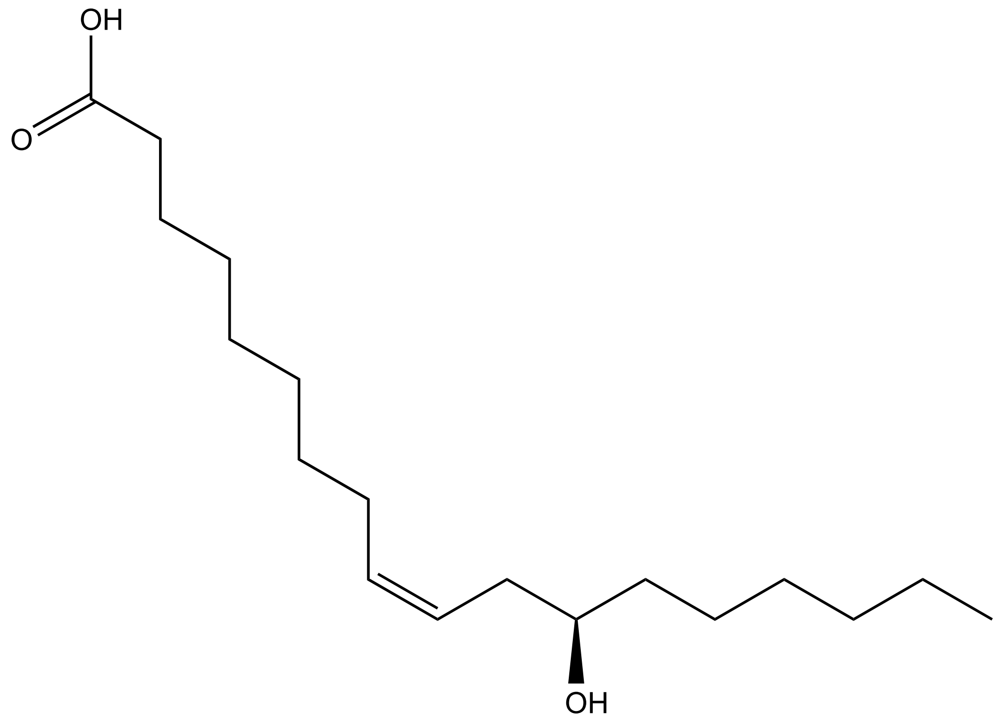
(Option B continues on the following page)

(Option B continued)

9. The castor plant is grown as a crop for its oil. Castor oil is mostly a triglyceride of the relatively rare fatty acid ricinoleic acid, whose structure is given below.



(a) State the molecular formula of ricinoleic acid. *[1]*

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(b) (i) Compare and contrast the structure of ricinoleic acid with stearic acid, whose structure is given in section 34 of the data booklet. *[3]*

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(Option B continues on the following page)

(Option B, question 9 continued)

(ii) State and explain how you would expect ricinoleic acid triglyceride to differ from stearic acid triglyceride in its tendency to undergo oxidative rancidity. *[2]*

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(c) Deduce the number of possible stereoisomers of ricinoleic acid. *[1]*

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(d) The castor seed contains ricin, a toxic protein which is fatal in small doses. During the oil extraction process, the toxin is inactivated by heating.

(i) Outline why ricin loses its toxic effects on being heated. *[1]*

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(ii) Examine why many countries no longer harvest the castor plant but rely instead on imports of castor oil from other countries. *[2]*

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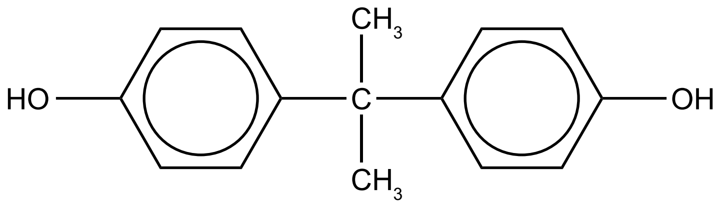
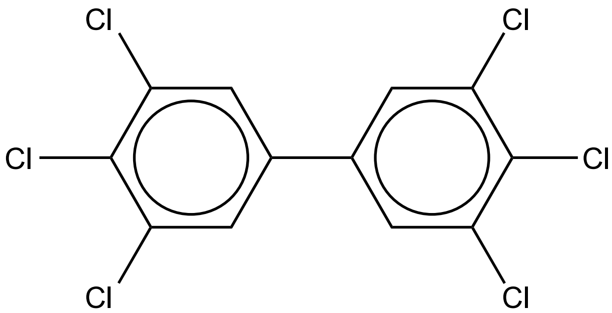
(Option B continues on the following page)

(Option B continued)

10. The figure below shows two examples of molecules known as xenoestrogens, a type of xenobiotic. They have effects on living organisms similar to those of the female hormone estrogen. These compounds are found in the environment and can be taken up by living organisms, where they may be stored in certain tissues.





(a) State what is meant by the term xenobiotic. *[1]*

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(b) With reference to their structures, outline why these xenobiotics are stored easily in animal fat. *[1]*

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(Option B continues on the following page)

(Option B, question 10 continued)

(c) One way to decrease the concentration of a xenobiotic in the environment is to develop a specific molecule, a "host", that can bind to it. The binding between the host and the xenobiotic forms a supramolecule.

State **three** types of association that may occur within the supramolecule between the host and the xenobiotic. *[1]*

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11. DNA is the molecule that carries genetic information in nearly all cells. Two months before Watson and Crick published their paper describing the double helical nature of DNA in 1953, Linus Pauling published a suggested structure for DNA based on a triple helix. Pauling's model, which was soon proved to be incorrect, had the phosphate groups facing into the core of the helix and the nitrogenous bases facing out.

(a) Suggest why Pauling's model would not have been a stable structure for DNA. *[2]*

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(b) DNA has the unusual property of being able to replicate. State the type and position of the bonds that break at the start of the replication process. *[1]*

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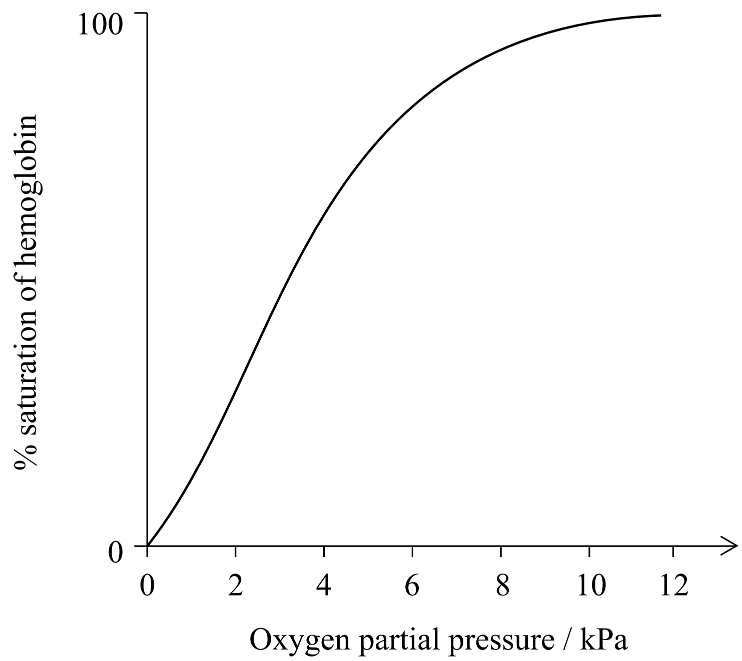
(Option B continues on the following page)

(Option B continued)

12. Hemoglobin is a protein with a quaternary structure. The graph below shows the relationship between the percentage saturation of hemoglobin with oxygen and the oxygen partial pressure, which is a measure of its concentration.



(a) Describe why the curve rises steeply in the range of approximately 2 – 6 kPa *[2]*

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(b) (i) Annotate the graph above to show how the oxygen binding curve for hemoglobin changes in the presence of an increased concentration of carbon dioxide. *[1]*

(Option B continues on the following page)

(Option B, question 12 continued)

(ii) Explain how the change you have drawn in part (b)(i) affects the oxygen saturation of the blood when it is close to cells that are actively respiring. *[2]*

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End of Option B

Option C — Energy

13. Plants convert solar energy into chemical energy. It would therefore be very convenient to use plant products, such as vegetable oils, directly as fuels for internal combustion engines.

(a) Visible light from the Sun is absorbed by chlorophyll. The structure of chlorophyll is given in section 35 of the data booklet. Identify the characteristic of the bonding in chlorophyll that enables it to absorb light in the visible region of the spectrum. *[1]*

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(b) (i) Identify the major problem involved in using vegetable oils directly as a fuel in a conventional internal combustion engine. *[1]*

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(ii) Transesterification of the oil overcomes this problem. State the reagents required for this process. *[1]*

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(Option C continues on the following page)

(Option C, question 13 continued)

(c) Plant products can also be converted to ethanol, which can be mixed with alkanes, such as octane, to produce a fuel. The table below gives some properties of these compounds.

Compound	**Molar mass / g mol^{-1}**	**Density / g dm^{-3}**	**ΔH_c / kJ mol^{-1}**	**Equation for combustion**
Ethanol	46.08	789	–1367	$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
Octane	114.26	703	–5470	$C_8H_{18}(l) + 12\frac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$

(i) The energy density of ethanol is 23 400 kJ dm^{-3}. Use data from the table above to determine the energy density of octane. *[1]*

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(ii) Use these results to outline why octane is the better fuel in vehicles. *[1]*

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(Option C continues on the following page)

(Option C, question 13 continued)

(iii) Use data from the table on page 26 to demonstrate that ethanol and octane give rise to similar carbon footprints. *[1]*

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(iv) Outline why, even though they have similar carbon footprints, using ethanol has less impact on levels of atmospheric carbon dioxide. *[1]*

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(Option C continues on the following page)

(Option C continued)

14. Nuclear power is an energy source that does not involve fossil fuels. Current nuclear technology is dependent on fission reactions.

(a) Commercial nuclear power technology developed very rapidly between 1940 and 1970. Outline why this occurred. *[1]*

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(b) The equation for a typical nuclear fission reaction is:

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \left(\rightarrow {}^{236}_{92}\text{U}\right) \rightarrow {}^{90}_{38}\text{Sr} + {}^{136}_{54}\text{Xe} + 10\,{}^{1}_{0}\text{n}$$

The masses of the particles involved in this fission reaction are shown below.

Mass of neutron	=	1.00867 amu
Mass of U-235 nucleus	=	234.99333 amu
Mass of Xe-136 nucleus	=	135.90722 amu
Mass of Sr-90 nucleus	=	89.90774 amu

Using these data and information from sections 1 and 2 of the data booklet, determine the energy released when one uranium nucleus undergoes fission. *[3]*

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(Option C continues on the following page)

(Option C, question 14 continued)

(c) The half-life of strontium-90 is 28.8 years. Using information from section 1 of the data booklet, calculate the number of years required for its radioactivity to fall to 10 % of its initial value. *[2]*

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(d) Nuclear fuels require the enrichment of natural uranium. Explain how this process is carried out, including the underlying physical principle. *[3]*

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(Option C continues on the following page)

(Option C continued)

15. Energy production presents many threats to the environment. One issue that has caused much controversy over recent years is the emission of greenhouse gases, which most scientists believe is a major cause of global warming.

(a) Explain the molecular changes that must occur in order for a molecule to absorb infrared light. *[2]*

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(b) (i) Carbon dioxide and water vapour are the most abundant greenhouse gases. Identify **one** other greenhouse gas and a natural source of this compound. *[1]*

Greenhouse gas:

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Natural source:

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(ii) Even though water vapour is the more potent greenhouse gas, there is greater concern about the impact of carbon dioxide. Suggest why this is the case. *[1]*

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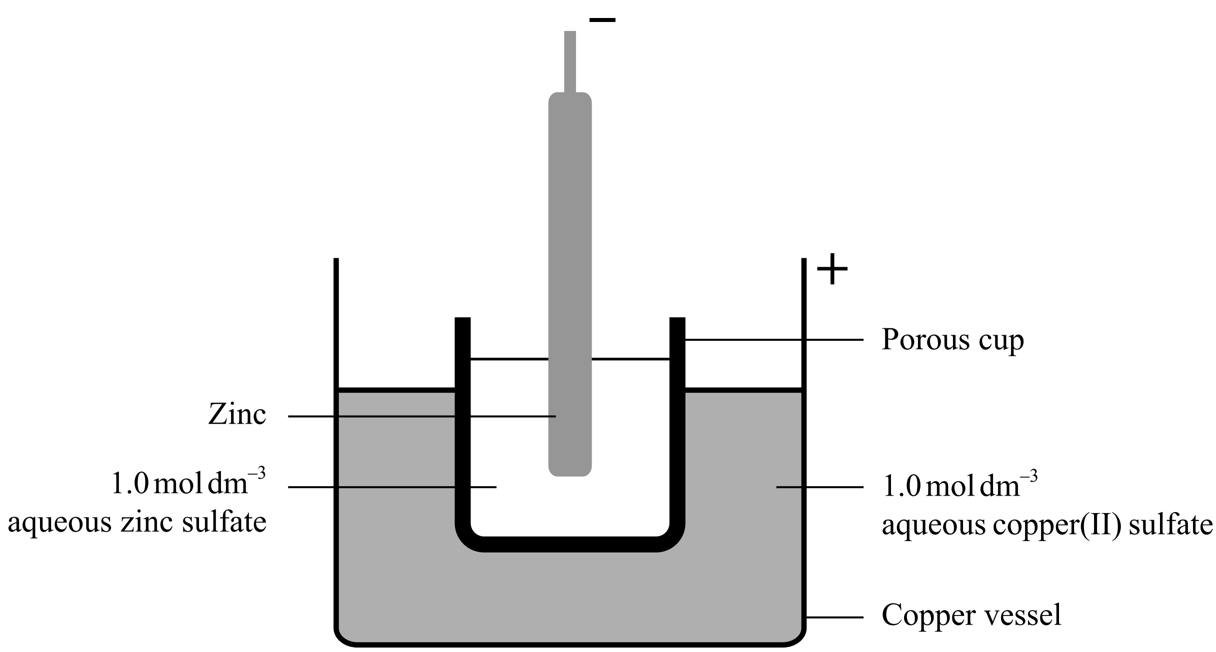
(Option C continues on the following page)

(Option C continued)

16. Providing electricity in remote locations, or in portable devices, is very important.

(a) One of the earliest devices used was the Daniell cell, illustrated below.



The porous cup allows the movement of ions between the two solutions, while preventing physical mixing. The standard potential of the cell, $E^{\ominus}_{cell}$, is 1.10 V.

(i) If the copper and the zinc electrodes are connected using a good electrical conductor, identify the process that initially limits the current. *[1]*

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(Option C continues on the following page)

(Option C, question 16 continued)

(ii) Outline, giving a reason, which solution should have its concentration increased in order to increase the cell potential. *[1]*

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(iii) In one remote location copper(II) sulfate was in short supply so the concentration of its solution had to be decreased to $0.1\,mol\,dm^{-3}$. Calculate the resulting cell potential, using information from sections 1 and 2 of the data booklet. *[2]*

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(iv) Suggest another effect that this decrease in the concentration of copper(II) sulfate will have on the cell as a source of electrical energy. *[1]*

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(Option C continues on the following page)

(Option C, question 16 continued)

(b) A modern solution to the provision of power for remote places is the dye-sensitized solar cell (DSSC). A Grätzel DSSC contains an organic dye molecule on the surface of a titanium dioxide, TiO_2, semiconductor that is in contact with an electrolyte containing iodide ions, I^-.

Explain its operation, including the importance of nanotechnology in its construction and its advantage over silicon-based photovoltaic devices. *[5]*

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End of Option C

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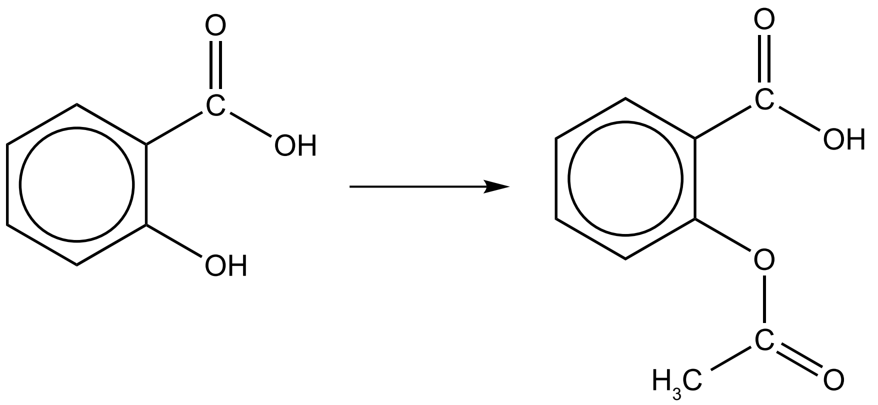
Option D — Medicinal chemistry

17. Salicylic acid has been used to relieve pain and reduce fevers for centuries, although it can be irritating to the stomach. In the 1800s it was discovered that converting it into acetylsalicylic acid reduces the stomach irritation while still allowing it to be effective.



Salicylic acid Acetylsalicylic acid (aspirin)

(a) Identify the type of reaction used to convert salicylic acid to acetylsalicylic acid. *[1]*

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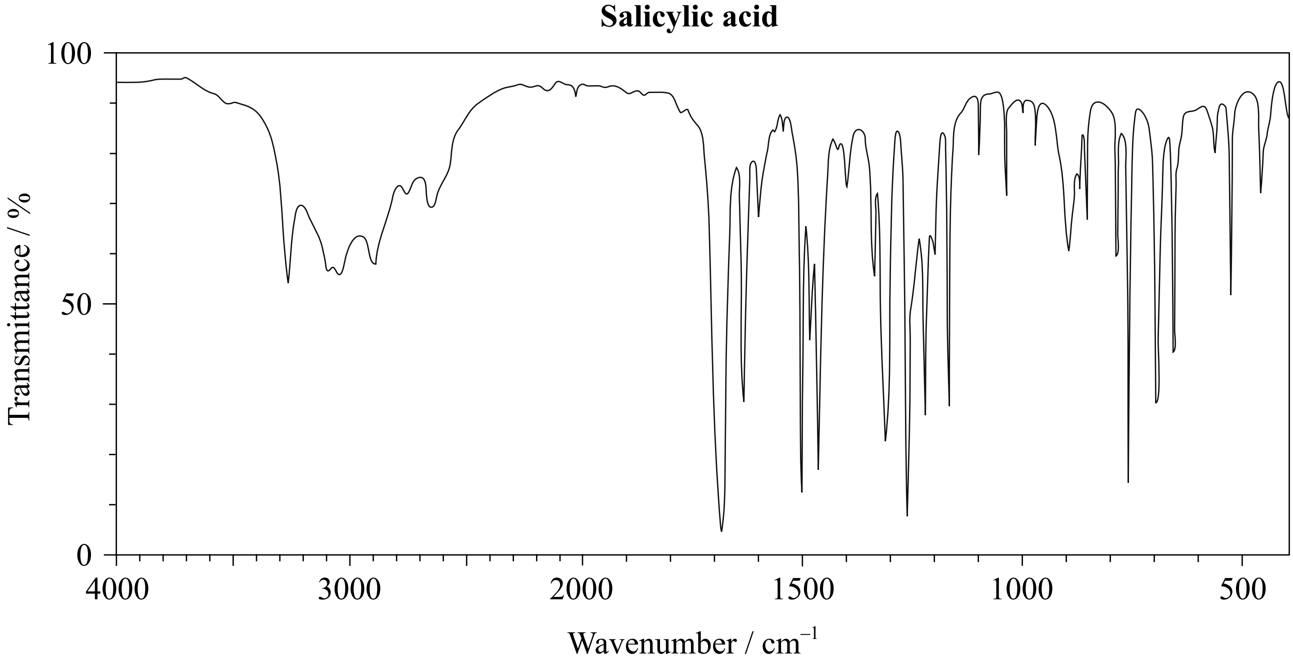
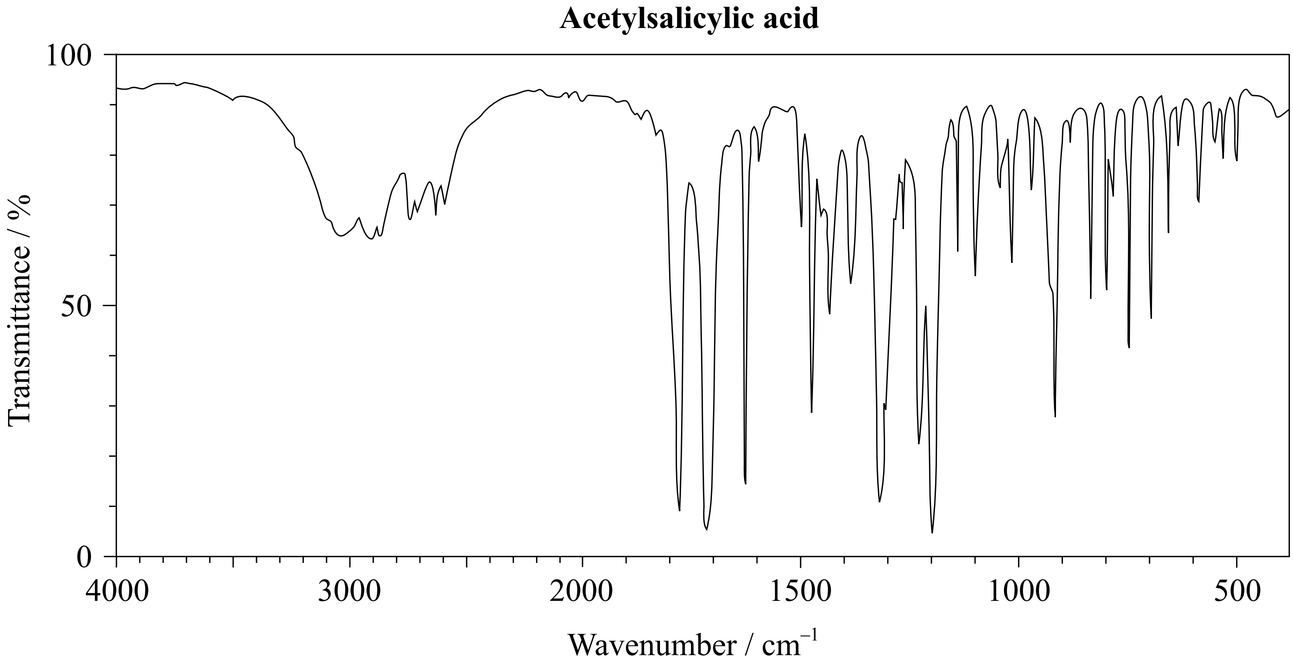
(Option D continues on the following page)

Turn over

(Option D, question 17 continued)

(b) The infrared (IR) spectra for salicylic acid and acetylsalicylic acid are shown below.





[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

(Option D continues on the following page)

(Option D, question 17 continued)

Using information from section 26 of the data booklet, compare and contrast the two spectra with respect to the bonds present. *[3]*

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(c) A modified version of aspirin is sometimes made by reacting it with a strong base, such as sodium hydroxide. Explain why this process can increase the bioavailability of the drug. *[3]*

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(Option D continues on the following page)

(Option D continued)

18. Recent advances in research into the viruses that cause flu have led to the production of two antiviral drugs, oseltamivir (Tamiflu®) and zanamivir (Relenza®).

(a) Outline why viruses are generally more difficult to target with drugs than bacteria. *[1]*

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(b) By reference to their molecular structures given in section 37 of the data booklet, state the formulas of **three** functional groups that are present in both oseltamivir and zanamivir and the formulas of **two** functional groups that are present in zanamivir only. *[3]*

Present in both:

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Present in zanamivir only:

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(c) Comment on how the widespread use of these drugs may lead to the spread of drug-resistant viruses. *[2]*

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(Option D continues on the following page)

(Option D continued)

19. Antacids help to neutralize excess hydrochloric acid produced by the stomach. The neutralizing power of an antacid can be defined as the amount in moles of hydrochloric acid that can be neutralized per gram of antacid.

(a) Formulate an equation to show the action of the antacid magnesium hydroxide. *[1]*

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(b) An antacid tablet with a mass of 0.200 g was added to 25.00 cm^3 of 0.125 mol dm^{-3} hydrochloric acid. After the reaction was complete, the excess acid required 5.00 cm^3 of 0.200 mol dm^{-3} sodium hydroxide to be neutralized. Determine the neutralizing power of the tablet. *[3]*

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(Option D continues on the following page)

(Option D continued)

20. Radiotherapy is widely used as part of the treatment for many types of cancer. It uses ionizing radiation to control or kill cancerous cells.

A promising development in this field is targeted alpha therapy, which uses alpha-emitting radionuclides specifically directed at the biological target.

(a) Explain **two** characteristics of alpha particles that enable them to be particularly effective in cancer treatments. *[2]*

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(b) (i) Other forms of radiotherapy use radionuclides that are beta emitters. Yttrium-90, ^{90}Y, is commonly used and undergoes beta decay with a half-life of 64 hours.

Formulate the nuclear equation for the decay of ^{90}Y. *[2]*

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(ii) Use information from section 1 of the data booklet to calculate how much of a 65.7 g sample of ^{90}Y would remain after 264 hours. *[2]*

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(Option D continues on the following page)

(Option D continued)

21. Taxol® is a chemotherapeutic drug used for the treatment of several types of cancer.

(a) Describe the original source and the environmental impact of obtaining Taxol® from this source. *[2]*

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(b) Outline a current "green chemistry" approach for isolating Taxol®, and why this is less harmful to the environment. *[2]*

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(c) The structure of Taxol® is shown in section 37 of the data booklet. It has been described as a "very chiral molecule". Explain the meaning of this statement and why processes to synthesize Taxol® chemically are complex and crucial to control. *[3]*

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End of Option D

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MARKSCHEME

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Paper 3

23 pages

Subject Details: Chemistry HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[15 marks]** and all questions from **ONE** option in Section B **[30 marks]**.
Maximum total = **[45 marks]**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***" on the line between the alternatives. Either answer can be accepted.

7. Words in angled brackets **‹ ›** in the "Answers" column are not necessary to gain the mark.

8. Words that are underlined are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. “ECF acceptable” will be displayed in the “Notes” column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.

14. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the “Notes” column, similarly, if the formula is specifically asked for, unless directed otherwise in the “Notes” column do not award a mark for a correct name.

15. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the “Notes” column.

16. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

SECTION A

Question			Answers	Notes	Total
1.	**a**	**i**	relative values ***OR*** compared with a standard ***OR*** not absolute measure ✓		**1**
	a	**ii**	high ODP for compounds with high Cl ***OR*** low ODP for compounds with less Cl ***OR*** zero ODP for compounds with no Cl ✓		**1**
	b		increasing atmospheric lifetime correlates with increasing GWP ✓ total contribution to global warming depends on length of time in atmosphere ***OR*** GWP depends on efficiency as greenhouse gas and atmospheric lifetime ✓	*Accept alternate answers based on sound scientific reasoning.*	**2**
	c	**i**	1,1,1,2-tetrafluoroethane ✓	*Allow without commas or dashes.*	**1**
	c	**ii**	$M\ (CH_2FCF_3) = (12.01 \times 2) + (1.01 \times 2) + (19.00 \times 4) = 102.04 \langle g\ mol^{-1} \rangle$ ✓ $\Delta H\ (\text{condensation } CH_2FCF_3) = -[0.217 \langle kJ\ g^{-1} \rangle \times 102.04 \langle g\ mol^{-1} \rangle] = -22.1 \langle kJ\ mol^{-1} \rangle$ ✓	*Award **[1 max]** for* $\Delta H = 22.1\,kJ$	**2**
	c	**iii**	atmospheric lifetime CO_2 much longer than CH_2FCF_3 ***OR*** after 100 years approx 30 % CO_2 still present whereas CH_2FCF_3 removed ✓ CO_2 from current emissions will continue to effect climate change/global warming far into the future ✓	*OWTTE*	**2**

Question			Answers	Notes	Total
2.	**a**		forgot to take account of water of crystallisation ***OR*** should have used 24.972 g ✓	*OWTTE*	**1**
	b		less uncertainty in the volume ***OR*** more precise ✓ takes into account volume change on dissolving ***OR*** concentration is for a given volume of solution not volume of solvent ✓		**2**
	c		filter ***OR*** centrifuge ✓ rinse (the solid) with water ✓ heat in an oven ***OR*** rinse with propanone/ethanol/volatile organic solvent and leave to evaporate ✓	*Award **[2]** for all 3, **[1]** for any 2.*	**2**
	d		taking a known mass of the solid to react directly with glucose ***OR*** not making the standard solution ✓	*OWTTE* *Accept any other valid answer based on sound scientific reasoning.*	**1**

SECTION B

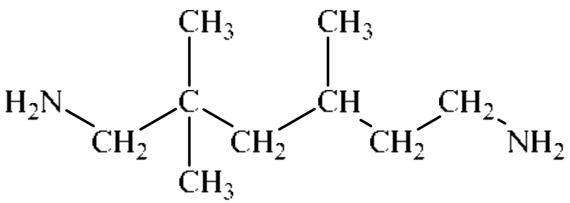
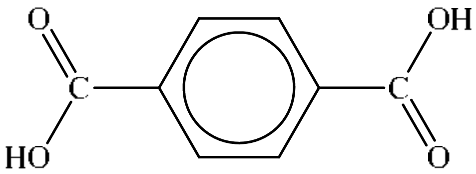
Option A — Materials

Question			Answers	Notes	Total
3.	**a**		rigid ***OR*** rod-shaped/long thin molecule ✓		**1**
	b	**i**	mixture of carbon containing compound and inert dilutant in gas/vapour phase ✓ passed over a heated metal catalyst ✓		**2**
	b	**ii**	(very) large surface area ✓		**1**

<table>
<tr><td>4.</td><td>a</td><td></td><td>
<table>
<tr><th>Compound</th><th>Magnesium oxide</th><th>Cobalt(II) oxide</th><th></th></tr>
<tr><td>Electronegativity difference</td><td>2.1</td><td>1.5</td><td>✓</td></tr>
<tr><td>Average electronegativity</td><td>2.35</td><td>2.65</td><td>✓</td></tr>
</table>
</td><td>Award [1] per correct row or column.</td><td>2</td></tr>
<tr><td></td><td>b</td><td></td><td>
<table>
<tr><th>Compound</th><th>Magnesium oxide</th><th>Cobalt(II) oxide</th><th></th></tr>
<tr><td>Bond type</td><td>Ionic</td><td>Polar covalent</td><td>✓</td></tr>
<tr><td>% covalent character</td><td>30 – 35</td><td>53 – 58</td><td>✓</td></tr>
</table>
</td><td>Award [1] per correct row or column.</td><td>2</td></tr>
</table>

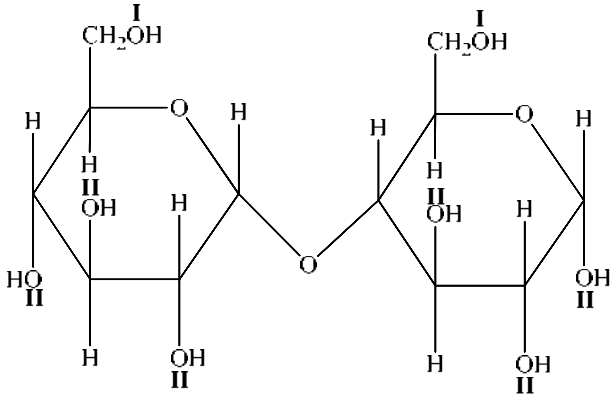
Question			Answers	Notes	Total
5.	**a**	**i**	mol $Mg^{2+} = \langle 0.25 \times 10 \times 10^{-6} = \rangle 2.5 \times 10^{-6} \langle mol \rangle$ ✓ mass $Mg^{2+} = \langle 24.31 \times 2.5 \times 10^{-6} = \rangle 6.08 \times 10^{-5}$ g ✓		**2**
	a	**ii**	627 kcps **and** it lies inside of the calibrated region ***OR*** 627 kcps **and** 12 kcps lies outside of calibrated region ✓	*Accept other correct suggestions, for example "Low values such as 12 kcps would have very high uncertainty".*	**1**
	b		$K_{sp} = [Mg^{2+}][OH^-]^2$ ✓ $[Mg^{2+}] = \frac{1}{4} \times 1.20 \times 10^{-11}$ ✓ $[Mg^{2+}] = 3.00 \times 10^{-12} \langle mol\,dm^{-3} \rangle$ ✓		**3**

Question			Answers	Notes	Total
6.	**a**		resin identification codes ✓ ensures uniformity for recycling ✓ ***OR*** addition/condensation ✓ classification into similar reaction types ✓ ***OR*** flexible ✓ direct towards appropriate uses ✓ ***OR*** brittle ✓ direct towards appropriate uses ✓	*OWTTE* *Accept "predict possible monomers". OWTTE* *Accept any other valid scientific classification with a justifiable scientific reason for* ***[2]****.*	**2**
	b		softens the polymer ✓ separates the polymer chains ***OR*** reduces intermolecular forces ✓		**2**
	c		all of the reagents end up in useful product ***OR*** atom economy is 100% ***OR*** there is no chemical waste ✓	*OWTTE*	**1**
	d		hydrogen chloride/HCl ***OR*** dioxin ✓		**1**

Question			Answers	Notes	Total
	e		polyamide ***OR*** condensation ✓  / $H_2NCH_2C(CH_3)_2CH_2CH(CH_3)CH_2CH_2NH_2$ **and**  / $HOOCC_6H_4COOH$	*Accept H_2N written as NH_2.* *Accept the acyl chloride.*	**2**

Question			Answers	Notes	Total
7.	**a**		bcc / body-centred cubic ✓ 8 ✓ 2 ✓		**3**
	b		mass of Nb in unit cell $= \langle \frac{2\times 92.91\times 10^{-3}}{6.02\times 10^{23}} = \rangle 3.087\times 10^{-25}$ ⟨kg⟩ ✓ volume of unit cell $= \langle (3.14\times 10^{-10})^3 = \rangle 3.096\times 10^{-29} \langle m^3 \rangle$ ✓ density $= \langle \frac{3.087\times 10^{-25}}{3.096\times 10^{-29}} \rangle = 9970 \langle kg\ m^{-3} \rangle$ ✓	*Award **[3]** for correct final answer.*	**3**
	c		⟨at low temperatures⟩ the positive ions in the lattice are attracted to a passing electron, distorting the lattice slightly ✓ a second electron with <u>opposite spin</u> is attracted to this ⟨slightly positively charged⟩ deformation ⟨and a coupling of the two electrons occurs⟩ ✓		**2**

Option B — Biochemistry

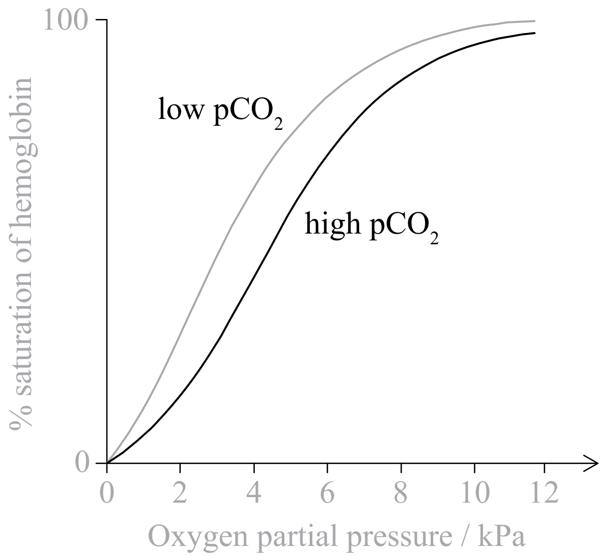
Question			Answers	Notes	Total
8.	**a**		 ✓	*Award mark for a correctly placed* ***I*** ***and*** *a correctly placed* ***II****.* *Allow* ***II*** *placed on hemiacetal.*	**1**
	b	**i**	$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$ ✓		**1**
	b	**ii**	catabolism ✓	*Accept hydrolysis.*	**1**
	c		at X (low pH) enzyme/protein protonated / positively charged / cationic (so unable to bind effectively) ✓ at Y (optimum pH) enzyme maximally able to bind to substrate/maltose ✓ at Z (high pH) enzyme/protein deprotonated / negatively charged / anionic (so unable to bind effectively) ✓	*Award* ***[1 max]*** *for reference to denaturation/change in shape of active site without explanation in terms of changes in ionization.*	**3**

Question			Answers	Notes	Total
8.	**d**		‹$\text{pH} = \text{p}K_a + \log\left\{\frac{[\text{A}^-]}{[\text{HA}]}\right\}$, butanoic acid $\text{p}K_a = 4.83$› $5.00 - 4.83 = \log\left(\frac{[\text{butanoate ion}]}{0.10}\right)$ **OR** $10^{0.17} = \frac{[\text{butanoate ion}]}{0.10} = 1.479$ ✓ $[\text{butanoate ion}] = 0.1479$ ‹mol dm^{-3}› ✓ if $1.00\,\text{dm}^3$, $0.10\,\text{mol dm}^{-3}$ butanoic acid $1.00\,\text{dm}^3$ of $0.1479\,\text{mol dm}^{-3}$ solution: $0.1479\,\text{mol} \times 110.01\,\text{g mol}^{-1} = 16.27\,\text{g}$ sodium butanoate ✓	*Accept alternate valid methods.*	**3**

Question			Answers	Notes	Total
9.	a		$C_{18}H_{34}O_3$ ✓		1
	b	i	both have 18 carbon atoms ✓ both have COOH/carboxylic acid group ***OR*** both are fatty acids ✓ ricinoleic acid has a <u>carbon-carbon</u> double bond/C=C/‹mono›unsaturated whereas stearic acid has all single C–C bonds/saturated ✓ ricinoleic acid has an OH/hydroxyl group ‹in the chain› whereas stearic acid does not ✓	*Do not accept just acids in M2* *Any 3 for **[3 max]**.*	**3 max**
	b	ii	ricinoleic acid more likely to undergo oxidative rancidity (than stearic acid) ✓ <u>carbon-carbon</u> double bond/C=C can be oxidised ✓		2
	c		4 ✓		1
	d	i	‹heating causes› denaturation ***OR*** ‹heating causes› loss of conformation ***OR*** ‹heating causes› change of shape ***OR*** ‹heating causes› inability to bind substrates ✓	*Do not accept inactivated.*	1
	d	ii	castor seeds contain toxins/ricin ***OR*** ingesting raw seeds can be fatal ✓ different health/safety standards in different countries ***OR*** richer countries exploit workers in less-developed/poorer countries ✓	*Accept alternate valid answers, such as economic considerations.*	2

Question			Answers	Notes	Total
10.	**a**		substance/chemical/compound found in organism not normally present ***OR*** compound foreign to living organism ✓	*Accept artificially synthesised/man-made compound in the environment/biosphere.*	**1**
	b		non-polar ***OR*** lipophilic ***OR*** structure based on phenyl/hydrocarbon ***OR*** hydrophobic interactions ***OR*** similar (non)polarity to fat ✓		**1**
	c		ionic bonds ✓ hydrogen bonds ✓ van der Waals' forces ✓ hydrophobic interactions ✓	*Award **[1]** for any 3 correct answers.* *Accept alternate valid answers other than covalent bonding*	**1 max**

11.	**a**		phosphate groups negatively charged/anionic so repulsion when close together/stacked ***OR*** negative charged/hydrophilic phosphate groups associate with aqueous exterior/surface ✓ nitrogenous bases hydrophobic/non-polar will not easily associate with aqueous exterior/surface ***OR*** non-polar groups form hydrophobic/non-polar internal environment ✓	*OWTTE* *OWTTE*	**2**
	b		hydrogen bonds between paired/complementary bases ✓	*Allow hydrogen bonds between A & T and C & G.*	**1**

Question			Answers	Notes	Total
12.	**a**		binding to the first polypeptide causes a conformational/3D change in shape ✓ facilitates the binding to the other polypeptides ***OR*** cooperative binding ✓		**2**
	b	**i**	 curve of same shape to the right of given graph ✓		**1**
	b	**ii**	respiration releases CO_2 ***OR*** high concentration of CO_2 near actively respiring cells ✓ percentage saturation of hemoglobin is lower as CO_2 increases ***OR*** hemoglobin lower affinity/binds less to oxygen at higher CO_2 ***OR*** oxyhemoglobin dissociates more easily/releases O_2 at higher CO_2 ✓		**2**

Option C — Energy

Question			Answers	Notes	Total
13.	**a**		extended system of delocalized ‹pi-›bonding/electrons ***OR*** extensive conjugation ✓		**1**
	b	**i**	viscosity too high ✓		**1**
	b	**ii**	alcohol **and** (strong) acid ***OR*** base ✓		**1**
	c	**i**	$\langle \frac{703 \times 5470}{114.26} = \rangle 33700 \langle \text{kJ dm}^{-3} \rangle$ ✓		**1**
	c	**ii**	more energy from a given volume of fuel ✓	*Accept greater energy density.*	**1**
	c	**iii**	ethanol: $\frac{1367}{2} = 683.5\,\text{kJ mol}^{-1}$ **and** octane: $\frac{5470}{8} = 683.8\,\text{kJ mol}^{-1}$ ***OR*** mass of CO_2 produced in the release of 1000 kJ ethanol: $\frac{2 \times 44.01 \times 1000}{1367} = 64.4\,\text{g}$ **and** octane: $\frac{8 \times 44.01 \times 1000}{1367} = 64.4\,\text{g}$ ✓	*Accept other methods that show the amount carbon dioxide produced for the same heat energy output is the same for both fuels.*	**1**
	c	**iv**	ethanol is a biofuel/produced from plant material ***OR*** growing plants absorbs carbon dioxide ✓		**1**

Question			Answers	Notes	Total
14.	**a**		nuclear power benefitted from the race to develop nuclear weapons ✓	*OWTTE* *Accept other valid explanations.*	**1**
	b		$\Delta m = \langle 234.99333 - 135.90722 - 89.907738 - [9 \times 1.00867] = \rangle\, 0.100342 \langle \text{amu} \rangle$ ✓ $= \langle 0.100342 \times 1.66 \times 10^{-27} \langle \text{kg} \rangle = \rangle\, 1.67 \times 10^{-28} \langle \text{kg} \rangle$ ✓ $E = \langle mc^2 = 1.67 \times 10^{-28} \times (3 \times 10^8)^2 = \rangle\, 1.50 \times 10^{-11} \langle \text{J} \rangle$ ✓	*Award **[3]** for correct final answer.*	**3**
	c		$\lambda = \langle \frac{\ln 2}{t_{½}} = \frac{\ln 2}{28.8} = \rangle\, 0.0241$ ✓ $t = \langle -\frac{1}{\lambda} \ln \frac{N}{N_0} = -\frac{\ln 0.1}{0.0241} = \rangle\, 95.7 \ \langle \text{years} \rangle$ ✓ ***OR*** $0.5^n = x$ $n = \langle \frac{\log x}{\log 0.5} = \frac{\log 0.1}{0.301} = \rangle\, 3.32$ ✓ time $= 28.3 \times 3.32 = 95.7 \ \langle \text{years} \rangle$ ✓	*Award **[2]** for correct final answer.*	**2**
	d		conversion to UF_6 ✓ different isotopes have different rates of diffusion ✓ gases diffuse at rate proportional to $(M_r)^{-½}$ ✓ diffusion produced by ultracentifuges ✓		**3 max**

Question			Answers	Notes	Total
15.	**a**		stretching ***OR*** bending ✓ causing a change in polarity/dipole moment ✓		**2**
	b	**i**	methane **and** anaerobic decomposition of organic matter ***OR*** digestion in animals ✓	*Accept other examples of greenhouse gases with correct <u>natural</u> sources.*	**1**
	b	**ii**	major sources of water vapour are natural rather than anthropogenic/due to humans ***OR*** levels of water vapour have remained almost constant whereas those of CO_2 have increased significantly in recent times ✓		**1**

16.	**a**	**i**	movement/diffusion of ions between the two solutions/through the porous cup ✓		**1**
	a	**ii**	$CuSO_4$/copper(II) sulfate **and** displaces equilibrium towards Cu/copper ***OR*** $CuSO_4$/copper(II) sulfate **and** makes Cu/copper half cell more positive ✓		**1**
	a	**iii**	$E = 1.10 - \left(\frac{298R}{2F}\right)\ln\frac{[Zn^{2+}]}{[Cu^{2+}]} = 1.10 - \left(\frac{298 \times 8.31}{2 \times 96500}\right)\ln\frac{1}{0.1} = 1.10 - 0.0295$ ✓ $E = 1.07 \langle V \rangle$ ✓	*Award **[2]** for correct final answer.*	**2**
	a	**iv**	run out of power much more rapidly ***OR*** would not last as long ***OR*** would not be able to produce as much electricity ✓		**1**

Question			Answers	Notes	Total
	b		*Operation*: light energy excites dye molecules ✓ (excited) dye molecules inject electrons into TiO_2 layer ***OR*** $dye \rightarrow dye^+ + e^-$ ✓ oxidized dye molecules oxidize/convert I^- to I_3^- ***OR*** $2\,dye^+ + 3I^- \rightarrow I_3^- + 2dye$ ***OR*** $dye^+ + e^- \rightarrow dye$ **and** $3I^- \rightarrow I_3^- + 2e^-$ ✓ electrons flow through external circuit back to counter electrode ✓ electrons reduce/convert I_3^- ions to I^- (at the counter electrode) ***OR*** $I_3^- + 2e^- \rightarrow 3I^-$ ✓ *Advantage*: dye sensitised cells can use light of lower energy/lower frequency/longer wavelength than silicon cells ✓ *Importance of nanotechnology*: nanoparticles ensure a large surface area ✓	*Any three for **[3 max]** for its operation.*	**5 max**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
17.	**a**		esterification ***OR*** condensation ✓		**1**
	b		*Difference*: only spectrum for salicylic acid has ‹strong broad› peak from 3200–3600 cm^{-1} for OH ‹in alcohol/phenol› ✓ *Similarities*: both have ‹strong› peaks from 1050–1410 cm^{-1} for C–O ‹in alcohol/phenol› ✓ both have ‹strong› peaks from1700–1750 cm^{-1} for C=O ‹in carboxylic acid› ✓ both have ‹broad› peaks from 2500–3000 cm^{-1} for OH ‹in carboxylic acid› ✓ both have peaks from 2850–3090 cm^{-1} for C–H ✓	*Accept "acetylsalicylic acid has two peaks in the 1700–1800 cm^{-1} range due to 2 different C=O".* *Award* ***[2 max]*** *for two of the following similarities.*	**3 max**
	c		reaction with NaOH produces ‹ionic› salt ***OR*** $C_6H_4(OH)(COOH) + NaOH \rightarrow C_6H_4(OH)(COONa) + H_2O$ ✓ increases ‹aqueous› solubility ‹for transport/uptake› ✓ higher proportion of drug/dosage reaches target region/cells ✓		**3**

Question			Answers	Notes	Total
18.	**a**		lack cell structure ***OR*** exist within host cell ***OR*** mutate easily and frequently ✓		**1**
	b		*Present in both*: NH_2 ✓ CONH ✓ C=C ✓ COC ✓ *Present in zanamivir only*: COOH **and** OH ✓	*For similarities, award **[2 max]** for any three correct, **[1 max]** for two correct, **[0]** for one correct.* *Accept C=N*	**3 max**
	c		exposure of viruses to the drug favours resistant strains ✓ resistant strains difficult to treat ***OR*** drugs should be used only when required ‹not as prophylactic› ✓	*OWTTE*	**2**

Question			Answers	Notes	Total
19.	a		$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$ ✓		1
	b		*n*(HCl added) $= \langle 0.02500 \times 0.125 = \rangle\, 0.00313 \langle mol \rangle$ ✓ *n*(HCl unreacted with tablet) $= n(NaOH) = 0.00500 \times 0.200 = 0.00100 \langle$mol HCl excess$\rangle$ *n*(HCl reacted with antacid) $= \langle 0.00313 - 0.00100 = \rangle\, 0.00213 \langle mol \rangle$ ✓ neutralizing power $\langle mol\ g^{-1} \rangle = \langle \frac{0.00213}{0.200} = \rangle\, 0.011$ ⟨mol HCl neutralized per g antacid⟩ ✓		3

20.	a		very high ionizing density **and** so a high probability of killing cells along their track ✓ short range **and** so minimise unwanted irradiation of normal tissue surrounding the targeted cancer cells ✓	*OWTTE*	2
	b	i	${}^{90}_{39}Y \rightarrow {}^{90}_{40}Zr + {}^{0}_{-1}e / {}^{0}_{-1}\beta$ ✓✓	*Award **[1]** for correctly balanced mass and proton numbers.* *Award **[1]** for identification of Zr.*	2
	b	ii	$N_t = (65.7)(0.5)^{264/64}$ ✓ $N_t = 3.77 \langle g \rangle$ ✓ ***OR*** number of half-lives $(n) = \frac{264}{64} = 4.125$ ✓ proportion remaining $= (0.5)^n = 0.0573$ so $m = 3.77\ g$ ✓		2

Question			Answers	Notes	Total
21.	a		obtained from the bark of ‹Pacific› yew tree ✓ harvesting bark kills the tree ***OR*** trees/habitat became endangered ✓		**2**
	b		obtained from needles of Pacific/European yew tree ***OR*** obtained from fungus ***OR*** fermentation process ✓ avoids production of waste/hazardous by-products ***OR*** (fermentation) avoids use of solvents/reagents ***OR*** resources used renewable ✓		**2**

21.	c		many/11 chiral carbon centres ✓ large number enantiomers/stereoisomers exist ✓ different enantiomers have different effects in the body ***OR*** some enantiomers may be physiologically harmful ✓ synthetic routes use chiral auxiliaries to control enantiomer produced ✓ low yields from multi-stage processes ✓		**3 max**

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CHEMISTRY
STANDARD LEVEL
PAPER 1

SPECIMEN PAPER

45 minutes

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is *[30 marks]*.

14 pages

The Periodic Table

Atomic number
Element
Relative atomic mass

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.01																	2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.90
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 ‡ Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Uut (286)	114 Uuq (289)	115 Uup (288)	116 Uuh (293)	117 Uus (294)	118 Uuo (294)

†	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
‡	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

1. What is the total number of atoms in 0.50 mol of 1,4-diaminobenzene, $H_2NC_6H_4NH_2$?
(Avogadro's constant (L or N_A) = 6.0×10^{23} mol^{-1}.)

A. 16.0×10^{23}

B. 48.0×10^{23}

C. 96.0×10^{23}

D. 192.0×10^{23}

2. What is the sum of the coefficients when the equation for the combustion of ammonia is balanced using the smallest possible whole numbers?

$$\_\_\_\ NH_3(g) + \_\_\_\ O_2(g) \rightarrow \_\_\_\ N_2(g) + \_\_\_\ H_2O(g)$$

A. 6

B. 12

C. 14

D. 15

3. Which changes of state are endothermic processes?

I. Condensing
II. Melting
III. Subliming

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

4. 5.00 g of calcium carbonate, when heated, produced 2.40 g of calcium oxide. Which is the correct expression for the percentage yield of calcium oxide? ($M_r(CaCO_3) = 100$; $M_r(CaO) = 56$.)

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

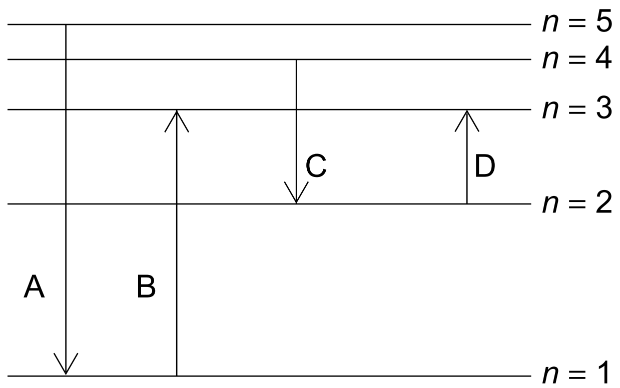
A. $\frac{56 \times 5.00 \times 100}{2.40}$

B. $\frac{2.40 \times 100 \times 100}{56 \times 5.00}$

C. $\frac{56 \times 5.00 \times 100}{2.40 \times 100}$

D. $\frac{2.40 \times 100}{56 \times 5.00}$

5. Which electronic transition would absorb the radiation of the shortest wavelength?



6. What are the numbers of protons, neutrons and electrons in the ion $^{238}_{92}X^{2+}$?

	Protons	Neutrons	Electrons
A.	146	92	144
B.	92	146	90
C.	92	146	94
D.	92	238	90

7. Which element is in the f-block of the periodic table?

A. Be

B. Ce

C. Ge

D. Re

8. Which property increases down group 1 of the periodic table?

A. Melting point

B. First ionization energy

C. Atomic radius

D. Electronegativity

9. Which is the best description of ionic bonding?

A. Electrostatic attraction between oppositely charged ions

B. Electrostatic attraction between positive ions and electrons

C. Electrostatic attraction of nuclei towards shared electrons in the bond between the nuclei

D. Electrostatic attraction between nuclei

10. Which has bonds with the greatest covalent character?

A. $SrCl_2$

B. $SiCl_4$

C. $SnCl_2$

D. Sn

11. Which bond is the **least** polar?

A. C=O in CO_2

B. C–H in CH_4

C. C–Cl in CCl_4

D. N–H in CH_3NH_2

12. Which substance has a high melting point and does not conduct electricity in any state?

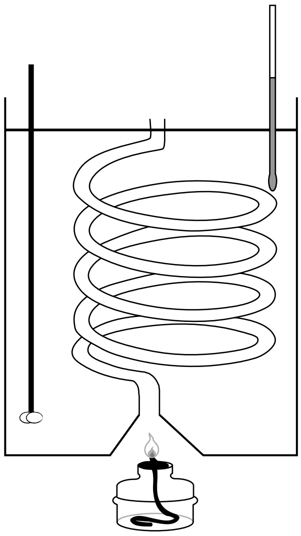
A. $PbBr_2$

B. Fe

C. NaCl

D. SiO_2

13. When 0.46 g of ethanol is burned under a water-filled calorimeter, the temperature of 500 g of water is raised by 3.0 K. (Molar mass of ethanol = 46 g mol^{-1}; specific heat capacity of water = 4.18 J g^{-1} K^{-1}; $q = mc\Delta T$.)



What is the expression for the enthalpy of combustion, ΔH_c, in kJ mol^{-1}?

A. $-\dfrac{500 \times 4.18 \times 3.0 \times 46}{0.46}$

B. $-\dfrac{500 \times 4.18 \times (273 + 3.0) \times 46}{0.46 \times 1000}$

C. $-\dfrac{500 \times 4.18 \times 3.0 \times 46}{0.46 \times 1000}$

D. $-\dfrac{0.46 \times 1000}{500 \times 4.18 \times 3.0 \times 46}$

14. Which reaction represents the average bond enthalpy of the C–H bond?

A. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + \frac{1}{2}H_2(g)$

B. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}CH_2(g) + \frac{1}{4}H_2(g)$

C. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + H(g)$

D. $\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(s) + H(g)$

15. Given the following information, what is the standard enthalpy of formation, $\Delta H^{\ominus}_{f}$, of methane?

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = \text{E kJ}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H = \text{F kJ}$$
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = \text{G kJ}$$

A. E + F + G

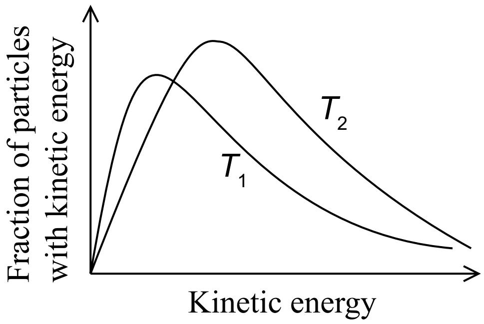
B. E + F – G

C. E + 2F + G

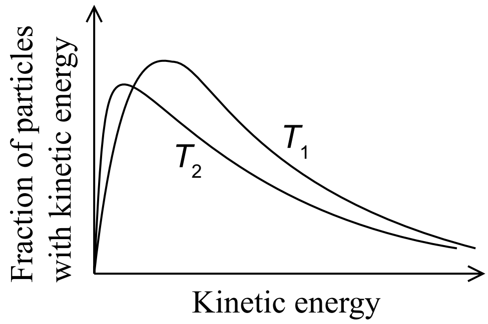
D. E + 2F – G

16. Which graph shows the Maxwell-Boltzmann energy distribution of a same amount of a gas at two temperatures, where T_2 is greater than T_1?

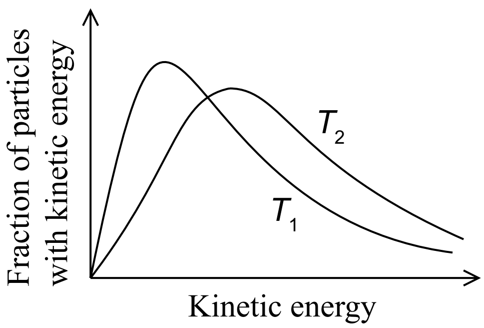
A.



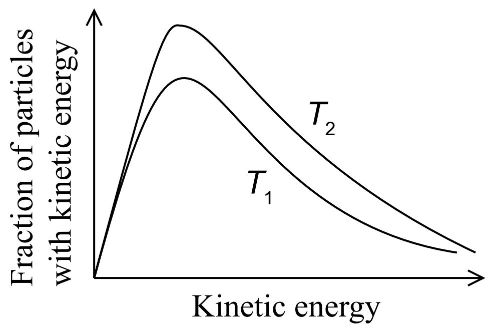
B.



C.



D.



17. Which changes increase the rate of this reaction, other conditions remaining constant?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

I. Using larger lumps of calcium carbonate

II. Increasing the temperature of the reaction mixture

III. Increasing the concentration of hydrochloric acid

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

18. Which conditions give the greatest equilibrium yield of methanal, $H_2CO(g)$?

$$CO(g) + H_2(g) \rightleftharpoons H_2CO(g) \qquad \Delta H = -1.8\,kJ$$

	Pressure	**Temperature**
A.	high	low
B.	high	high
C.	low	high
D.	low	low

19. Which of the following is **not** amphiprotic?

A. H_2O

B. HPO_4^{2-}

C. $H_2PO_4^{-}$

D. H_3O^{+}

20. Which compound will react with dilute hydrochloric acid, HCl(aq), to give off a gas?

A. $Cu_2O(s)$

B. $Cu(OH)_2(s)$

C. $CuCO_3(s)$

D. $CuO(s)$

21. The equations below represent reactions involved in the Winkler method for determining the concentration of dissolved oxygen in water:

$$2Mn(OH)_2(s) + O_2(aq) \rightarrow 2MnO(OH)_2(s)$$
$$MnO(OH)_2(s) + 2H_2SO_4(aq) \rightarrow Mn(SO_4)_2(s) + 3H_2O(l)$$
$$Mn(SO_4)_2(s) + 2I^-(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2SO_4^{2-}(aq)$$
$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

What is the amount, in mol, of thiosulfate ions, $S_2O_3^{2-}(aq)$, needed to react with the iodine, $I_2(aq)$, formed by 1.00 mol of dissolved oxygen?

A. 2.00

B. 3.00

C. 4.00

D. 6.00

22. What are the products when molten sodium chloride is electrolysed?

	Cathode	Anode
A.	hydrogen	chlorine
B.	sodium	chloride
C.	sodium	chlorine
D.	chlorine	sodium

23. Which is propyl propanoate?

A. $CH_3CH_2CH_2OOCCH_2CH_3$

B. $CH_3CH_2CH_2COOCH_2CH_3$

C. $CH_3CH_2CH_2COCH_2CH_3$

D. $CH_3CH_2CH_2OCH_2CH_2CH_3$

24. Which are consecutive members of a homologous series?

A. CH_4, CH_3Cl, CH_2Cl_2

B. HCOOH, CH_3COOH, C_2H_5COOH

C. C_2H_2, C_2H_4, C_2H_6

D. HCOOH, HCHO, CH_3OH

25. Which could form an addition polymer?

A. $H_2NCH_2CHCHCH_2NH_2$

B. $H_2N(CH_2)_6CO_2H$

C. $HO(CH_2)_2CO_2H$

D. $H_2N(CH_2)_6NH_2$

26. A compound decolorizes bromine water in the dark. Which statement is correct?

A. It contains C=C and is an alkene.

B. It contains C–C and is an alkene.

C. It contains C=C and is an alkane.

D. It contains C–C and is an alkane.

27. How can a systematic error be minimized?

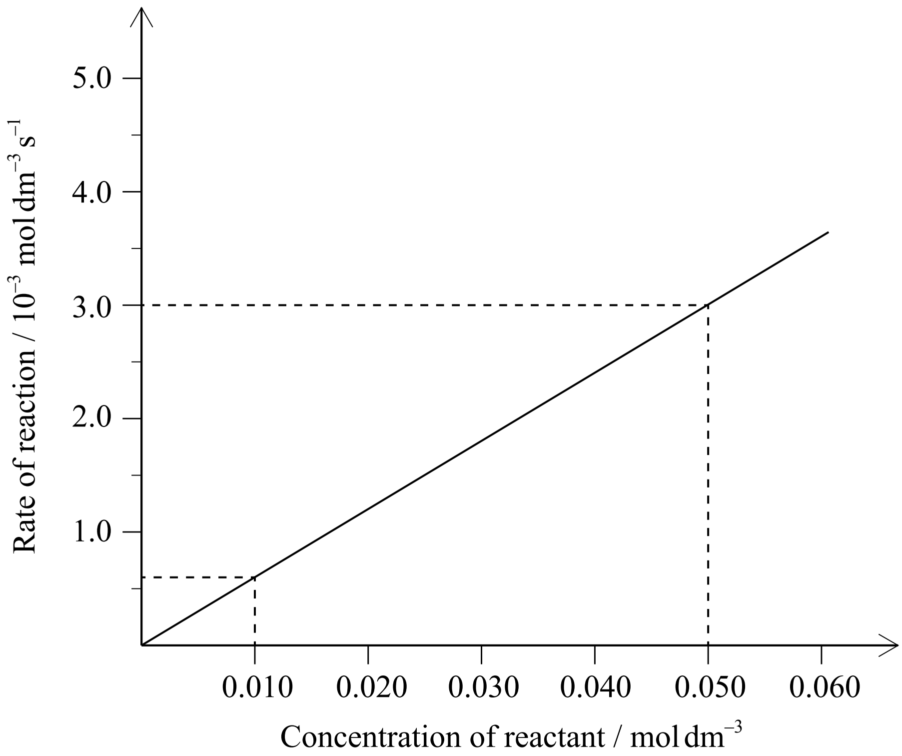
A. By taking the reading many times

B. By repeating the experiment many times

C. By using a more accurate measuring device

D. By evaluating and modifying the method

28. Which combination in the table correctly states the value and units of the gradient?



	Value	Units
A.	$\dfrac{3.0\times10^{-3}-0.6\times10^{-3}}{0.050-0.010}$	s^{-1}
B.	$\dfrac{3.0\times10^{-3}-0.6\times10^{-3}}{0.050-0.010}$	s
C.	$\dfrac{0.050-0.010}{3.0\times10^{-3}-0.6\times10^{-3}}$	s^{-1}
D.	$\dfrac{0.050-0.010}{3.0\times10^{-3}-0.6\times10^{-3}}$	s

29. Which part of the electromagnetic spectrum is used by ^{1}H NMR spectroscopy?

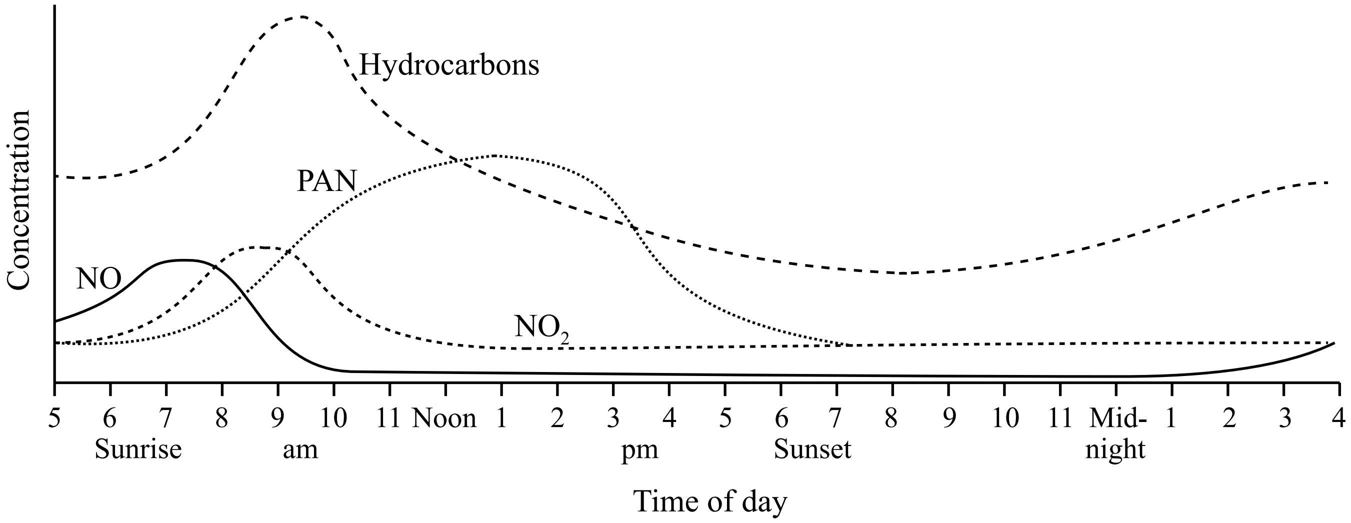
A. γ rays

B. X-rays

C. Microwaves

D. Radio waves

30. The graph shows the concentration of some pollutants in a city over a 24-hour period.



Which of the following could **not** be inferred from the graph?

A. Hydrocarbons cause less harm to health than PAN.

B. An increase in hydrocarbons is caused by the morning rush hour.

C. PAN concentration increases as the intensity of sunlight increases.

D. NO_2 production follows the production of NO.

SPEC/4/CHEMI/SPM/ENG/TZ0/XX/M

MARKSCHEME

SPECIMEN PAPER

CHEMISTRY

Standard Level

Paper 1

2 pages

1.	B	16.	C	31.	–	46.	–
2.	D	17.	C	32.	–	47.	–
3.	C	18.	A	33.	–	48.	–
4.	B	19.	D	34.	–	49.	–
5.	B	20.	C	35.	–	50.	–
6.	B	21.	C	36.	–	51.	–
7.	B	22.	C	37.	–	52.	–
8.	C	23.	A	38.	–	53.	–
9.	A	24.	B	39.	–	54.	–
10.	B	25.	A	40.	–	55.	–
11.	B	26.	A	41.	–	56.	–
12.	D	27.	D	42.	–	57.	–
13.	C	28.	A	43.	–	58.	–
14.	C	29.	D	44.	–	59.	–
15.	D	30.	A	45.	–	60.	–

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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

SPECIMEN PAPER

1 hour 15 minutes

Examination code

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- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the *Chemistry data booklet* is required for this paper.
- The maximum mark for this examination paper is *[50 marks]*.

*Answer **all** questions. Write your answers in the boxes provided.*

1. Two IB students carried out a project on the chemistry of bleach.

(a) The bleach contained a solution of sodium hypochlorite, NaClO(aq). The students determined experimentally the concentration of hypochlorite ions, ClO^-, in the bleach.

Experimental procedure:

- The bleach solution was first diluted by adding 25.00 cm^3 of the bleach to a 250 cm^3 volumetric flask. The solution was filled to the graduation mark with deionized water.

- 25.00 cm^3 of this solution was then reacted with excess iodide in acid.

$$ClO^-(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow Cl^-(aq) + I_2(aq) + H_2O(l)$$

- The iodine formed was titrated with 0.100 mol dm^{-3} sodium thiosulfate solution, $Na_2S_2O_3$(aq), using starch indicator.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The following data were recorded for the titration:

	First titre	**Second titre**	**Third titre**
Final burette reading of 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) (in cm^3 ± 0.05)	23.95	46.00	22.15
Initial burette reading of 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) (in cm^3 ± 0.05)	0.00	23.95	0.00

(i) Calculate the volume, in cm^3, of 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) required to react with the iodine to reach the end point. *[1]*

. . . .

. . . .

(This question continues on the following page)

(Question 1 continued)

(ii) Calculate the amount, in mol, of $Na_2S_2O_3(aq)$ that reacts with the iodine. *[1]*

. . . .
. . . .

(iii) Calculate the concentration, in $mol\,dm^{-3}$, of hypochlorite ions in the **diluted** bleach solution. *[1]*

. . . .
. . . .
. . . .

(iv) Calculate the concentration, in $mol\,dm^{-3}$, of hypochlorite ions in the **undiluted** bleach solution. *[1]*

. . . .
. . . .

(This question continues on the following page)

(Question 1 continued)

(b) Some of the group 17 elements, the halogens, show variable valency.

(i) Deduce the oxidation states of chlorine and iodine in the following species. *[1]*

NaClO:

. . . .

I_2:

. . . .

(ii) Deduce, with a reason, the oxidizing agent in the reaction of hypochlorite ions with iodide ions in part (a). *[1]*

. . . .

. . . .

. . . .

(iii) From a health and safety perspective, suggest why it is not a good idea to use hydrochloric acid when acidifying the bleach. *[1]*

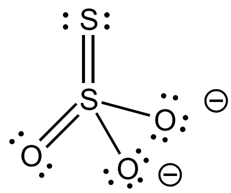
. . . .

. . . .

(This question continues on the following page)

(Question 1 continued)

(iv) The thiosulfate ion, $S_2O_3^{2-}$, is an interesting example of oxidation states. The sulfur atoms can be considered to have an oxidation state of +6 on one atom and –2 on the other atom. Discuss this statement in terms of your understanding of oxidation state. *[2]*



Lewis (electron dot) structure of thiosulfate

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question 1 continued)

(c) The various changes that have been made to the definitions of oxidation and reduction show how scientists often broaden similarities to general principles.

Combustion is also a redox type of reaction.

With reference to the combustion reaction of methane, explore **two** different definitions of oxidation, choosing one which is valid and one which may be considered not valid.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$ *[2]*

Valid:

. . . .

. . . .

. . . .

Not valid:

. . . .

. . . .

. . . .

(d) (i) State the **condensed** electron configuration of sulfur. *[1]*

. . . .

(ii) Deduce the orbital diagram of sulfur, showing all the orbitals present in the diagram. *[1]*

2. One of the main constituents of acid deposition is sulfuric acid, H_2SO_4. This acid is formed from the sulfur dioxide pollutant, SO_2.

A mechanism proposed for its formation is:

$$HO\bullet(g) + SO_2(g) \rightarrow HOSO_2(g)$$
$$HOSO_2(g) + O_2(g) \rightarrow HOO\bullet(g) + SO_3(g)$$
$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

(a) (i) State what the symbol (•) represents in the species shown in this mechanism. *[1]*

. . . .

. . . .

(ii) Draw one valid Lewis (electron dot) structure for each molecule below. *[2]*

Molecule	**Lewis (electron dot) structure**
SO_2	
H_2O	

(This question continues on the following page)

(Question 2 continued)

(iii) Deduce the name of the electron domain geometry and the molecular geometry for each molecule. *[2]*

	Electron domain geometry	**Molecular geometry**
SO_2	. . . .	. . . .
H_2O	. . . .	. . . .

(iv) Deduce the bond angles in SO_2 and H_2O. *[1]*

SO_2:

. . . .

H_2O:

. . . .

(This question continues on the following page)

(Question 2 continued)

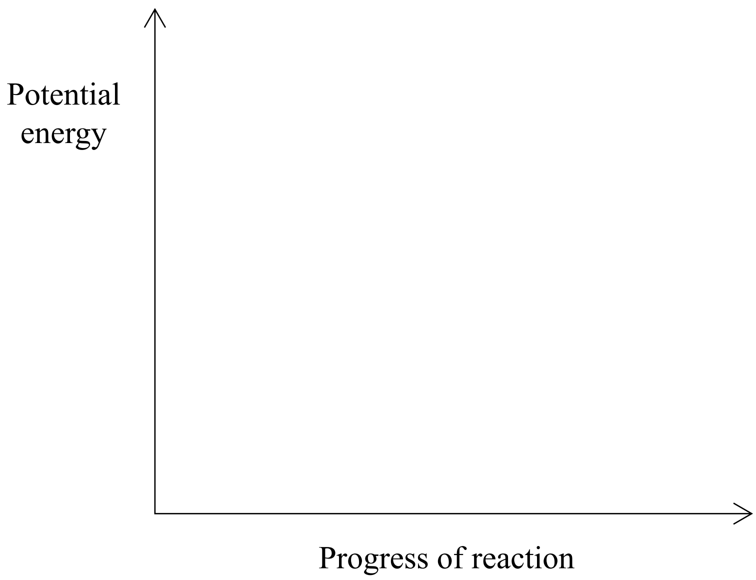
(v) Consider the following equilibrium between the two oxides of sulfur, sulfur dioxide and sulfur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -198\,kJ$$

Predict, with a reason, in which direction the position of equilibrium will shift for each of the changes listed below. *[3]*

Change	**Shift**	**Reason**
Increase in temperature	. . . .	. . . .
Increase in pressure	. . . .	. . . .
Addition of a catalyst to the mixture	. . . .	. . . .

(vi) Sketch the potential energy profile for the forward reaction in part (v) to show the effect of a catalyst on the activation energy, E_{act}. *[2]*



(This question continues on the following page)

(Question 2 continued)

(vii) Sulfuric acid, H_2SO_4, can be described as a Brønsted–Lowry acid. State what you understand by this description. *[1]*

. . . .

(viii) The hydrogen sulfate anion, HSO_4^-, is amphiprotic, so can act as an acid or a base. In the reaction of HSO_4^- with the hydronium cation, H_3O^+, identify the two species acting as bases.

$$HSO_4^-(aq) + H_3O^+(aq) \rightleftharpoons H_2SO_4(aq) + H_2O(l)$$ *[1]*

. . . .

(ix) Other compounds present in acid rain are formed from nitrogen dioxide, NO_2. Formulate an equation for the reaction of nitrogen dioxide with water. *[1]*

. . . .

3. Many automobile manufacturers are developing vehicles that use hydrogen as a fuel.

(a) Suggest why such vehicles are considered to cause less harm to the environment than those with internal combustion engines. *[1]*

. . . .

. . . .

(b) Hydrogen can be produced from the reaction of coke with steam:

$$C(s) + 2H_2O(g) \rightarrow 2H_2(g) + CO_2(g)$$

Using information from section 12 of the data booklet, calculate the change in enthalpy, ΔH, in $kJ\,mol^{-1}$, for this reaction. *[2]*

. . . .

. . . .

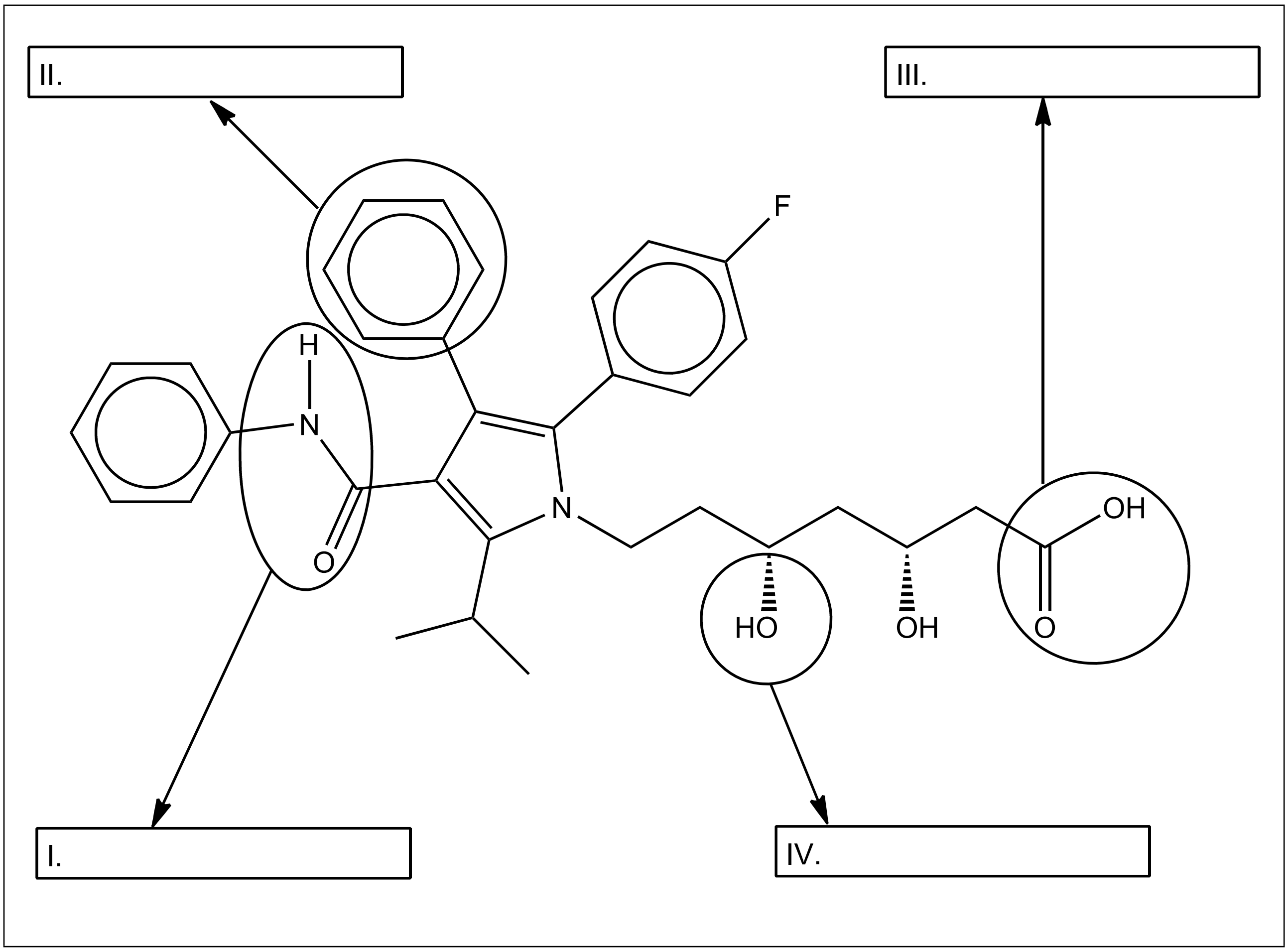
. . . .

. . . .

4. The biopharmaceutical industry is now a global contributor to the world economy.

(a) Atorvastatin, a drug used to lower cholesterol, recently gained attention from the global media.

Atorvastatin has the structure shown below.



Identify the **four** functional groups, I, II, III and IV. *[2]*

(This question continues on the following page)

(Question 4 continued)

(b) Bute, a painkiller used on horses, has caused widespread concern recently because analytical tests showed that it entered the food chain through horse meat labelled as beef. The drug is suspected of causing cancer.

(i) Analysis of a sample of bute carried out in a food safety laboratory gave the following elemental percentage compositions by mass:

Element	**Percentage**
C	73.99
H	6.55
N	9.09
O	Remainder

Calculate the empirical formula of bute, showing your working. *[3]*

. . . .
. . . .
. . . .
. . . .
. . . .
. . . .

(ii) The molar mass, M, of bute, is 308.37 $g\,mol^{-1}$. Calculate the molecular formula. *[1]*

. . . .
. . . .
. . . .

(This question continues on the following page)

(Question 4 continued)

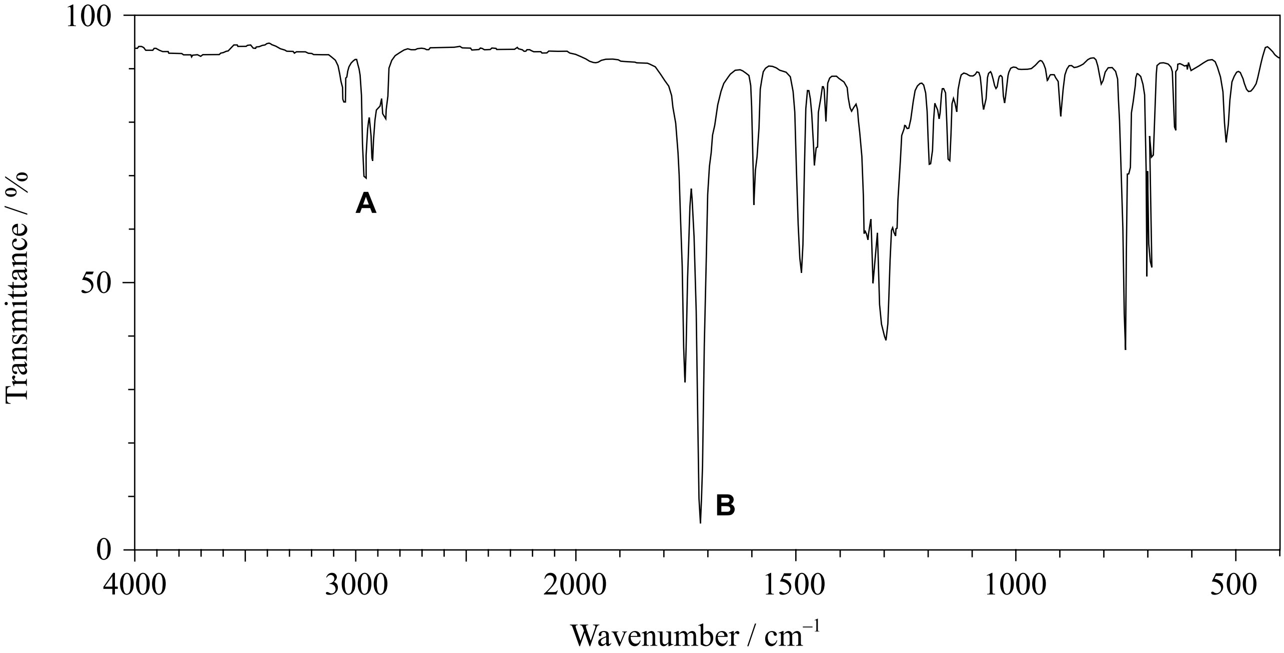
(iii) Deduce the degree of unsaturation (index of hydrogen deficiency – IHD) of bute. *[1]*

. . . .

. . . .

. . . .

(iv) The infrared (IR) spectrum of bute is shown below.



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

Using information from section 26 of the data booklet, identify the bonds corresponding to **A** and **B**. *[1]*

A: . . . .

B: . . . .

(This question continues on the following page)

(Question 4 continued)

(v) Based on analysis of the IR spectrum, predict, with an explanation, one bond containing oxygen and one bond containing nitrogen that could **not** be present in the structure. *[2]*

Bond containing oxygen not present in structure:

. . . .

Bond containing nitrogen not present in structure:

. . . .

Explanation:

. . . .

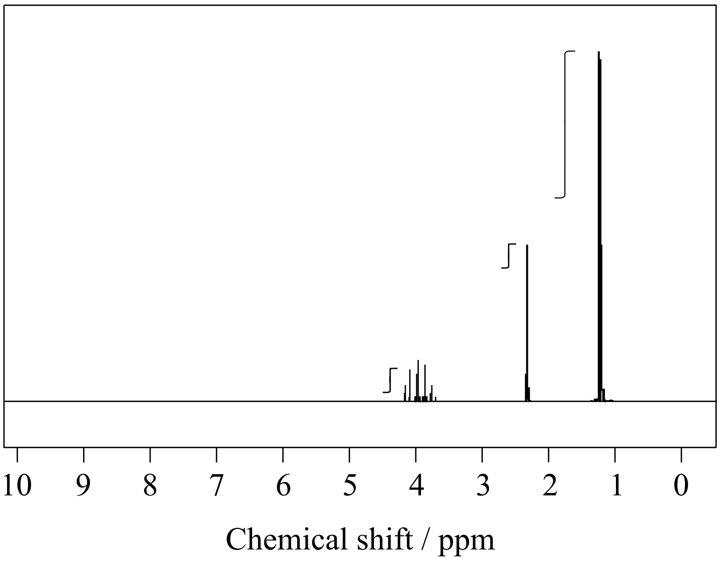
. . . .

. . . .

(This question continues on the following page)

(Question 4 continued)

(c) An alcohol, **X**, of molecular formula C_3H_8O, used as a disinfectant in hospitals, has the following ^1H NMR spectrum.



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

The three peaks in the ^1H NMR spectrum of **X** have chemical shift values centred at $\delta = 4.0$, 2.3 and 1.2 ppm.

(i) From the integration trace, estimate the ratio of hydrogen atoms in different chemical environments. *[1]*

. . . .

. . . .

(ii) Deduce the full structural formula of **X**. *[1]*

(This question continues on the following page)

(Question 4 continued)

(iii) **Y** is an isomer of **X** containing a different functional group. State the condensed structural formula of **Y**. *[1]*

. . . .
. . . .

(iv) Compare and contrast the expected mass spectra of **X** and **Y** using section 28 of the data booklet. *[2]*

One similarity:

. . . .
. . . .
. . . .

One difference:

. . . .
. . . .
. . . .

(This question continues on the following page)

(Question 4 continued)

(v) Both **X** and **Y** are soluble in water. Deduce whether or not both **X** and **Y** show hydrogen bonding with water molecules, representing any hydrogen bonding present by means of a diagram. *[2]*

. . . .

. . . .

(vi) **X** reacts with acidified potassium dichromate(VI) solution to form **Q** and with ethanoic acid to form **W**. Deduce the condensed structural formula of **Q** and **W**. *[2]*

Q:

. . . .

W:

. . . .

(This question continues on the following page)

(Question 4 continued)

(vii) Apply IUPAC rules to state the name of compound **Q**. *[1]*

. . . .

Please **do not** write on this page.

Answers written on this page
will not be marked.

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MARKSCHEME

SPECIMEN

CHEMISTRY

Standard Level

Paper 2

10 pages

Subject Details: Chemistry SL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions. Maximum total = **[50 marks]**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***" on the line between the alternatives. Either answer can be accepted.

7. Words in angled brackets **‹ ›** in the "Answers" column are not necessary to gain the mark.

8. Words that are <u>underlined</u> are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "ECF acceptable" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

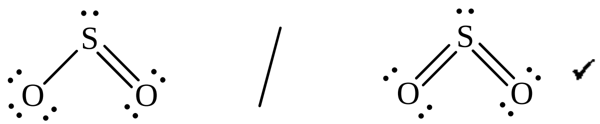
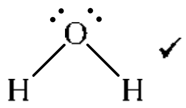
14. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column, similarly, if the formula is specifically asked for, unless directed otherwise in the "Notes" column do not award a mark for a correct name.

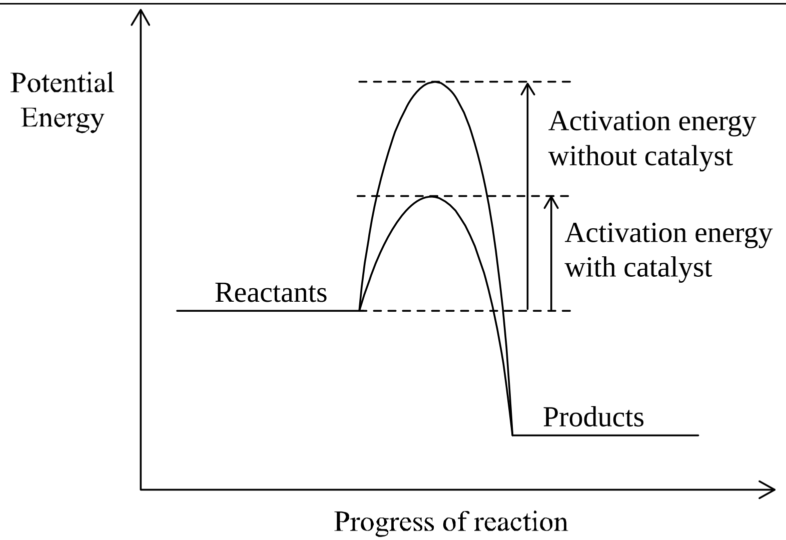
15. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

16. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

Question			Answers	Notes	Total
1.	**a**	**i**	‹$(22.05+22.15)(0.5)=$›22.10‹cm^3› ✓		**1**
	a	**ii**	$\left\langle \frac{22.10\times 0.100}{1000}=\right\rangle 2.21\times10^{-3}$ / 0.00221‹mol› ✓		**1**
	a	**iii**	$\left\langle \frac{0.5\times 2.21\times10^{-3}\times1000}{25.00}=\right\rangle 4.42\times10^{-2}$ / 0.0442‹$mol\,dm^{-3}$› ✓		**1**
	a	**iv**	‹$4.42\times10^{-2}\times10=$›$4.42\times10^{-1}$ / 0.442‹$mol\,dm^{-3}$› ✓		**1**
	b	**i**	*NaClO*: +1 ‹for chlorine› **and** I_2: 0 ‹for iodine› ✓		**1**
	b	**ii**	ClO^- since chlorine reduced/gains electrons ***OR*** ClO^- since oxidation state of chlorine changes from +1 to –1/decreases ***OR*** ClO^- since it loses oxygen / causes iodide to be oxidized ✓		**1**
	b	**iii**	produces chlorine ‹gas›/Cl_2 ‹on reaction with ClO^-› which is toxic ✓	*OWTTE*	**1**
	b	**iv**	oxidation states are not real ***OR*** oxidation states are just used for electron book-keeping purposes ✓ average oxidation state of sulfur calculated to be +2 ✓ but the two sulfurs are bonded differently/in different environments in thiosulfate so have different oxidation states ✓	*OWTTE*	**2 max**

Question			Answers	Notes	Total
	c		*Valid:* addition of oxygen signifies an oxidation reaction so C is oxidized ***OR*** loss of hydrogen signifies an oxidation reaction so C is oxidized ***OR*** oxidation state of C changes from –4 to +4/increases ✓ *Not valid:* loss of electrons might suggest formation of ionic product but not valid since CO_2 is covalent ***OR*** loss of electrons might suggest formation of ionic product but not valid since reaction only involves neutral molecules ✓	*OWTTE*	**2**
	d	**i**	$[Ne]3s^2 3p^4$ ✓	*Electrons must be given as superscript.*	**1**
	d	**ii**	[↿⇂] $1s^2$ [↿⇂] $2s^2$ [↿⇂][↿⇂][↿⇂] $2p^6$ [↿⇂] $3s^2$ [↿⇂][↿][↿] $3p^4$ ✓		**1**

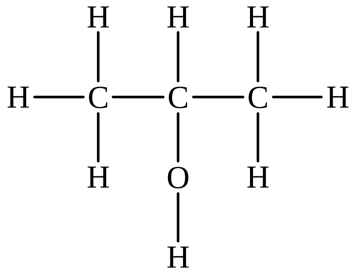
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>2.</td><td>a</td><td>i</td><td>radical / unpaired electron ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>a</td><td>ii</td><td><table><tr><th>Molecule</th><th>Lewis (electron dot) structure</th></tr><tr><td>SO_2</td><td></td></tr><tr><td>H_2O</td><td></td></tr></table></td><td>Lines, x’s or dots may be used to represent electron pairs.</td><td>2</td></tr>
<tr><td></td><td>a</td><td>iii</td><td><table><tr><th></th><th>Electron domain geometry</th><th>Molecular geometry</th></tr><tr><td>SO_2</td><td>trigonal/triangular planar</td><td>bent/v-shaped/angular✓</td></tr><tr><td>H_2O</td><td>tetrahedral</td><td>bent/v-shaped/angular✓</td></tr></table></td><td>Award [1 max] for either both electron domain geometries correct OR for either both molecular geometries correct.</td><td>2</td></tr>
<tr><td></td><td>a</td><td>iv</td><td>SO_2: Accept any angle in the range greater than 115° but less than 120°.
and
H_2O: 104.5° ✓</td><td>Experimental value is 119°</td><td>1</td></tr>
</table>

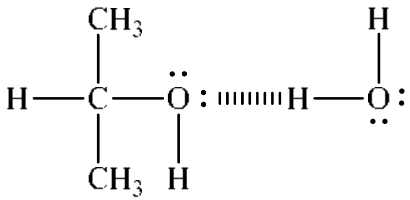
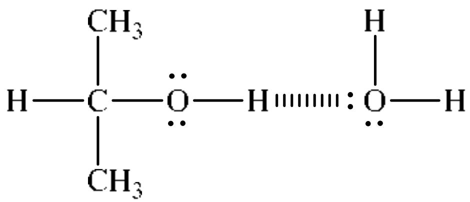
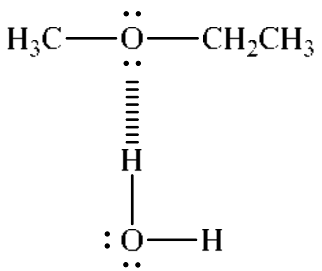
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>2</td><td>a</td><td>v</td><td>
<table>
<tr><th>Change</th><th>Shift</th><th>Reason</th></tr>
<tr><td>Increase in temperature</td><td>LHS</td><td>since ‹forward› exothermic reaction/ $\Delta H < 0$ ✓</td></tr>
<tr><td>Increase in pressure</td><td>RHS</td><td>since fewer ‹gaseous› molecules on RHS ✓</td></tr>
<tr><td>Addition of a catalyst to the mixture</td><td>No change</td><td>since affects rate of forward and reverse reactions equally ✓</td></tr>
</table>
</td><td></td><td>3</td></tr>
<tr><td></td><td>a</td><td>vi</td><td>


correct positions of reactants and products ✓
correct profile with labels showing activation energy with and without a catalyst ✓</td><td></td><td>2</td></tr>
<tr><td></td><td>a</td><td>vii</td><td>proton/H^+ donor ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>a</td><td>viii</td><td>$HSO_4^-(aq)$ and $H_2O(l)$ ✓</td><td></td><td>1</td></tr>
<tr><td></td><td>a</td><td>ix</td><td>$2NO_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$ ✓</td><td>Ignore state symbols.</td><td>1</td></tr>
</table>

Question			Answers	Notes	Total
3.	**a**		<u>only</u> water/H_2O produced ‹so non-polluting› ✓		**1**
	b		$\Delta H = [(-393.5)] - [(2)(-241.8)]$ ✓ +90.1‹kJ› ✓	*Award **[2]** for correct final answer.*	**2**

4.	**a**		*I:* carboxamide ✓ *II:* phenyl ✓ *III:* carboxyl / carboxy ✓ *IV:* hydroxyl ✓	*Award **[2]** for all four correct, **[1]** for two or three correct.* *Do not allow benzene.* *Do not allow carboxylic/alkanoic acid.* *Do not allow alcohol or hydroxide.*	**2 max**
	b	**i**	$n_C : \left\langle \frac{73.99}{12.01} \right\rangle = 6.161\,(\text{mol})$ **and** $n_H : \left\langle \frac{6.55}{1.01} \right\rangle = 6.49\,(\text{mol})$ **and** $n_N : \left\langle \frac{9.09}{14.01} \right\rangle = 0.649\,(\text{mol})$ **and** $n_O : \left\langle \frac{10.37}{16.00} \right\rangle = 0.6481\,(\text{mol})$ ✓ $n_C : n_H : n_N : n_O = 9.5 : 10 : 1 : 1$ ✓ *Empirical formula*: $C_{19}H_{20}N_2O_2$ ✓	*Award **[2 max]** for correct final answer without working.*	**3**
	b	**ii**	$C_{19}H_{20}N_2O_2$ ✓		**1**
	b	**iii**	⟨(0.5)(40 – 20 + 4 – 2) = ⟩11 ✓		**1**
	b	**iv**	*A:* C–H **and** *B:* C=O		**1**
	b	**v**	O–H **and** N–H ✓ frequencies/stretches due to O–H and N–H occur above 3200 ‹cm^{-1}› which are not present in IR of *bute* ✓		**2**
	c	**i**	1:1:6 ✓		**1**

Question			Answers	Notes	Total
	c	**ii**	 ✓		**1**
	c	**iii**	$CH_3OCH_2CH_3$ ✓		**1**
	c	**iv**	*Similarity:* both have fragment corresponding to $(M_r - 15)^+$ / both have $m/z = 45$ ✓ *Difference:* **X** has fragment corresponding to $(M_r - 17)^+$ / **X** has $m/z = 43$ ***OR*** **X** has fragment corresponding to $(M_r - 43)^+$ / **X** has $m/z = 17$ ***OR*** **Y** has fragment corresponding to $(M_r - 31)^+$ / **Y** has $m/z = 29$ ***OR*** **Y** has fragment corresponding to $(M_r - 29)^+$ / **Y** has $m/z = 31$ ✓	*Allow "both have same molecular ion peak/M^+ / both have m/z = 60". However in practice the molecular ion peak is of low abundance and difficult to observe for propan-2-ol.*	**2**

Question			Answers	Notes	Total
4.	**c**	**v**	both **X** and **Y** will exhibit hydrogen bonding with water molecules ✓ diagrams showing hydrogen bonding ✓ X:  **OR**  Y: 		**2**
	c	**vi**	*I:* CH_3COCH_3 ✓ *II:* $CH_3COOCH(CH_3)_2$ ✓		**2**
	c	**vii**	propanone ✓		**1**

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CHEMISTRY
STANDARD LEVEL
PAPER 3

Candidate session number

SPECIMEN PAPER

Examination code

1 hour

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer all of the questions from one of the options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the *Chemistry data booklet* is required for this paper.
- The maximum mark for this examination paper is *[35 marks]*.

Option	Questions
Option A — Materials	3 – 6
Option B — Biochemistry	7 – 9
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34 pages

SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

1. Compounds used to generate cooling in refrigerators and air-conditioning systems are known as refrigerants. A refrigerant undergoes a reversible change of state involving vaporization and condensation. The search for suitable refrigerants has occupied chemists for approximately 200 years.

Previously, the most popular refrigerants were chlorofluorocarbons (CFCs), but these have been replaced, first by hydrochlorofluorocarbons (HCFCs) and more recently by hydrofluorocarbons (HFCs).

Some data on examples of these three classes of refrigerants are shown below.

Class	**Compound**	**ODP**[1]	**GWP**[2] **over 100 years**	ΔH_{vap}[3] **/ kJ mol^{-1}**	**Atmospheric lifetime / years**
CFC	CCl_3F	1.0	4000	24.8	45
CFC	CCl_2F_2	1.0	8500	20.0	102
HCFC	$CHCl_2CF_3$	0.02	90	26.0	1
HCFC	$CHClF_2$	0.05	1810	20.2	12
HFC	CH_2FCF_3	0	1100	–	–
HFC	CHF_2CF_3	0	3500	30.0	32

[1] ODP: The ozone depletion potential (ODP) is a relative measure of the amount of degradation to the ozone layer caused by the compound. It is compared with the same mass of CCl_3F, which has an ODP of 1.0.

[2] GWP: The global warming potential (GWP) is a relative measure of the total contribution of the compound to global warming over the specified time period. It is compared with the same mass of CO_2, which has a GWP of 1.0.

[3] ΔH_{vap}: Defined as the energy required to change one mole of the compound from a liquid to a gas.

(a) (i) Explain why the values for ODP and GWP have no units. *[1]*

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(This question continues on the following page)

(Question 1 continued)

(ii) By making reference to the chemical formulas and ODP values of the compounds, comment on the hypothesis that chlorine is responsible for ozone depletion. *[1]*

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(b) Use data from the table to interpret the relationship between the atmospheric lifetime of a gas and its GWP. *[2]*

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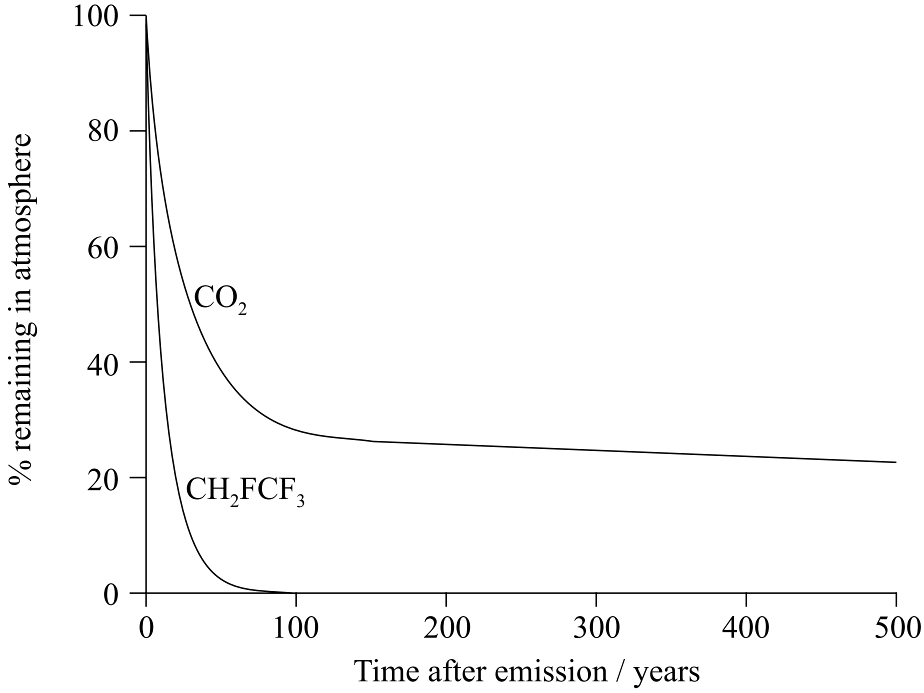
(This question continues on the following page)

(Question 1 continued)

(c) The graph shows the change in levels with time of equal masses of CO_2 and CH_2FCF_3 introduced into the atmosphere.



(i) Apply IUPAC rules to state the name of CH_2FCF_3. *[1]*

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(ii) The $\Delta H_{vaporization}$ for CH_2FCF_3 is $217\,kJ\,kg^{-1}$. Calculate the value of the enthalpy change for the condensation of one mole of CH_2FCF_3. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(iii) With reference to the graph on page 4, comment on the atmospheric lifetime of CO_2 relative to CH_2FCF_3, and on the likely influence of this on climate change. *[2]*

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2. Thomas wants to determine the empirical formula of red-brown copper oxide. The method he chooses is to convert a known amount of copper(II) sulfate into this oxide. The steps of his procedure are:

- Make $100\,cm^3$ of a $1\,mol\,dm^{-3}$ solution using hydrated copper(II) sulfate crystals.
- React a known volume of this solution with alkaline glucose in order to convert it to red-brown copper oxide.
- Separate the precipitated oxide and find its mass.

(a) Thomas calculates that he needs $0.1\times[1\times 63.55 + 1\times 32.07 + 4\times 16.00] = 15.962 \pm 0.001$ g of the copper(II) sulfate to make the solution. Outline the major error in his calculation. *[1]*

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(b) He now adds $100 \pm 1\,cm^3$ of water from a measuring/graduated cylinder and dissolves the copper(II) sulfate crystals. A friend tells him that for making standard solutions it is better to use a volumetric flask rather than adding water from a measuring cylinder. Suggest **two** reasons why a volumetric flask is better. *[2]*

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(c) Thomas now heats $25\,cm^3$ of the solution with excess alkaline glucose to convert it to a suspension of red-brown copper oxide. Describe how he can obtain the pure, dry solid product. *[2]*

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(This question continues on the following page)

(Question 2 continued)

(d) Using the same chemical reactions, suggest how Thomas' method to determine the mass of red-brown copper oxide that could be obtained from a known mass of copper(II) sulfate crystals might be simplified to produce more precise results. *[1]*

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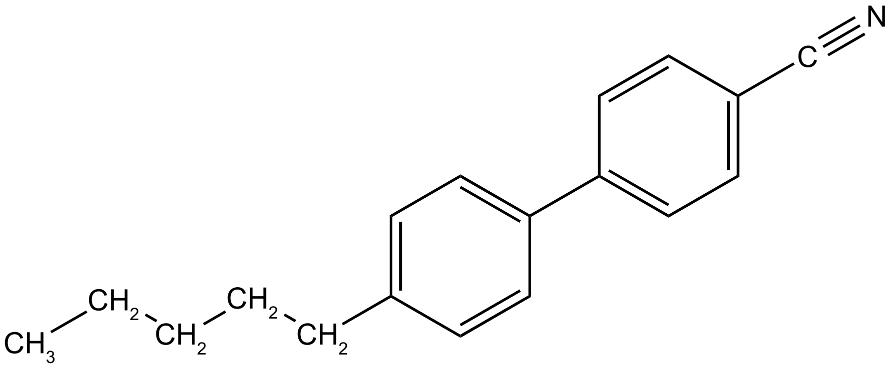
SECTION B

*Answer **all** of the questions from **one** of the options. Write your answers in the boxes provided.*

Option A — Materials

3. (a) The molecule shown below is frequently used in liquid-crystal displays (LCDs).



Identify a physical characteristic of this molecule that allows it to exist in a liquid-crystal state. *[1]*

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(b) (i) Describe the chemical vapour deposition (CVD) method for the production of carbon nanotubes. *[2]*

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(ii) Many modern catalysts use carbon nanotubes as a support for the active material. State the major advantage of using carbon nanotubes. *[1]*

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(Option A continues on the following page)

(Option A continued)

4. Different metal oxides are widely used in the production of ceramic materials and their function is closely linked to the type of bonding present in the compound.

(a) Both magnesium oxide and cobalt(II) oxide are incorporated into ceramics. Use section 8 of the data booklet to calculate values to complete the table below. *[2]*

Compound	**Magnesium oxide**	**Cobalt(II) oxide**
Electronegativity difference	. . . .	. . . .
Average electronegativity	. . . .	. . . .

(b) Predict the bond type and percentage covalent character of each oxide, using section 29 of the data booklet. *[2]*

Compound	**Magnesium oxide**	**Cobalt(II) oxide**
Bond type	. . . .	. . . .
% covalent character	. . . .	. . . .

(Option A continues on the following page)

(Option A continued)

5. Magnesium is an essential component of chlorophyll and traces of it can be found in various fluids from plants. Its concentration may be estimated using inductively coupled plasma optical emission spectroscopy (ICP-OES).

(a) Outline what the specific plasma state involved in ICP spectroscopy comprises. *[1]*

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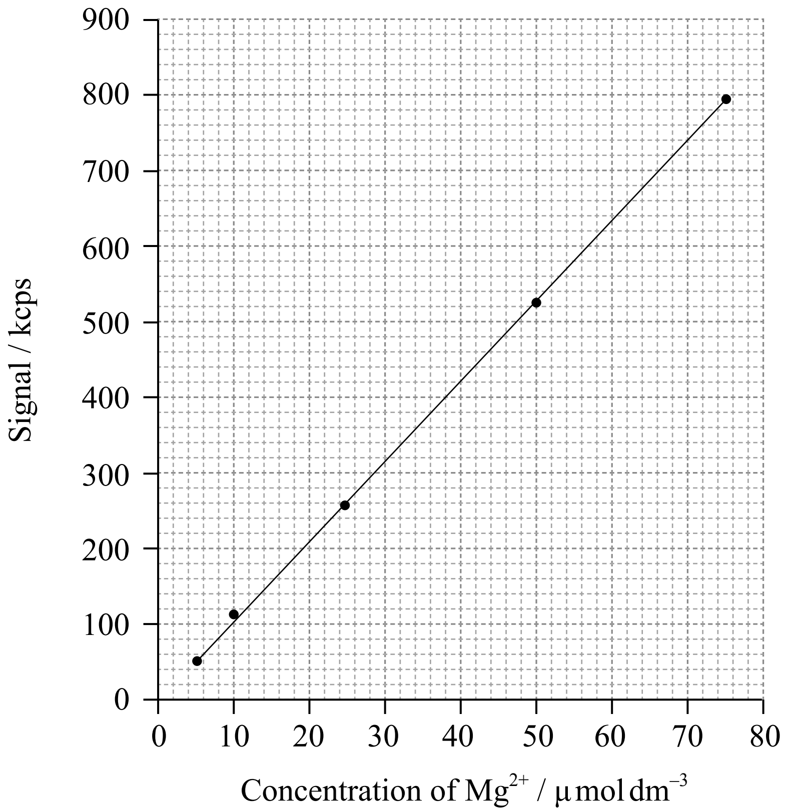
(b) An ICP-OES calibration curve for magnesium is shown in the graph below.



(Option A continues on the following page)

(Option A, question 5 continued)

(i) Determine the mass of magnesium ions present in $250\,cm^3$ of a solution with a concentration of $10\,\mu mol\,dm^{-3}$. *[2]*

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(ii) Taking into account your answer to part (b)(i), discuss how the solutions for this calibration curve could be produced. *[2]*

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(iii) Two solutions gave count rates of 627 kcps and 12 kcps respectively. Justify which solution could be more satisfactorily analysed using this calibration graph. *[1]*

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(Option A continues on the following page)

(Option A continued)

6. Plastics, such as PVC and melamine, are widely used in modern society.

(a) PVC is thermoplastic, whereas melamine is thermosetting. State one other way in which scientists have tried to classify plastics, and outline why the classification you have chosen is useful. *[2]*

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(b) It was almost a century after the discovery of PVC before Waldo Semon turned it into a useful plastic by adding plasticizers. State and explain the effect plasticizers have on the properties of PVC. *[2]*

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(c) Justify why, in terms of atom economy, the polymerization of PVC could be considered “green chemistry”. *[1]*

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(Option A continues on the following page)

(Option A, question 6 continued)

(d) In spite of the conclusion in part (c), many consider that PVC is harmful to the environment. Identify **one** specific toxic chemical released by the combustion of PVC. *[1]*

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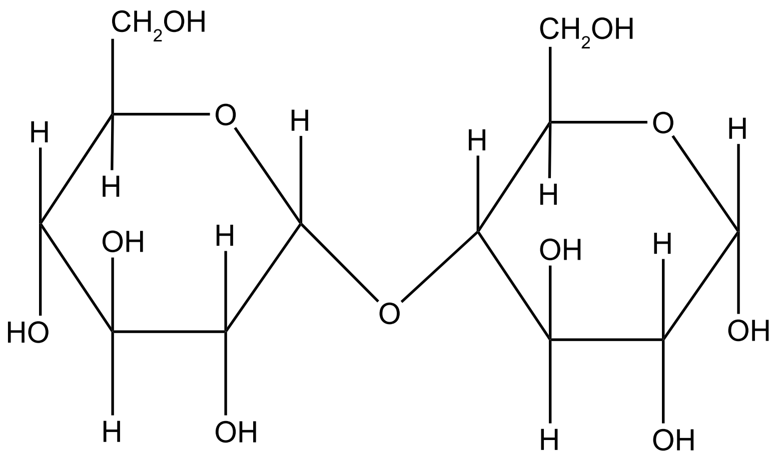
End of Option A

Option B — Biochemistry

7. The diagram below shows the structure of a disaccharide called maltose.



(a) Identify on the diagram one primary alcohol group by marking I on the oxygen, **and** one secondary alcohol group by marking II on the oxygen. *[1]*

(b) (i) Formulate an equation, using molecular formulas, to show the conversion of this molecule into its monomers. *[1]*

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(ii) Identify the type of metabolic process shown in part (b)(i). *[1]*

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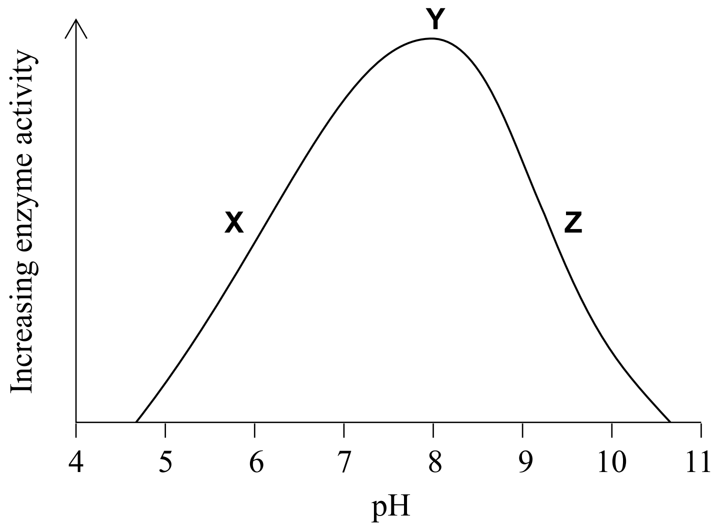
(Option B continues on the following page)

(Option B, question 7 continued)

(c) The reaction in part (b) is catalysed by the enzyme maltase. Experiments were carried out to investigate the rate of breakdown of maltose in the presence of maltase over a range of pH values from 4 to 11. The results are shown below.



Describe how the activity of the enzyme changes with pH, including in your answer specific reference to how the pH is affecting the enzyme at **X**, **Y** and **Z**. *[3]*

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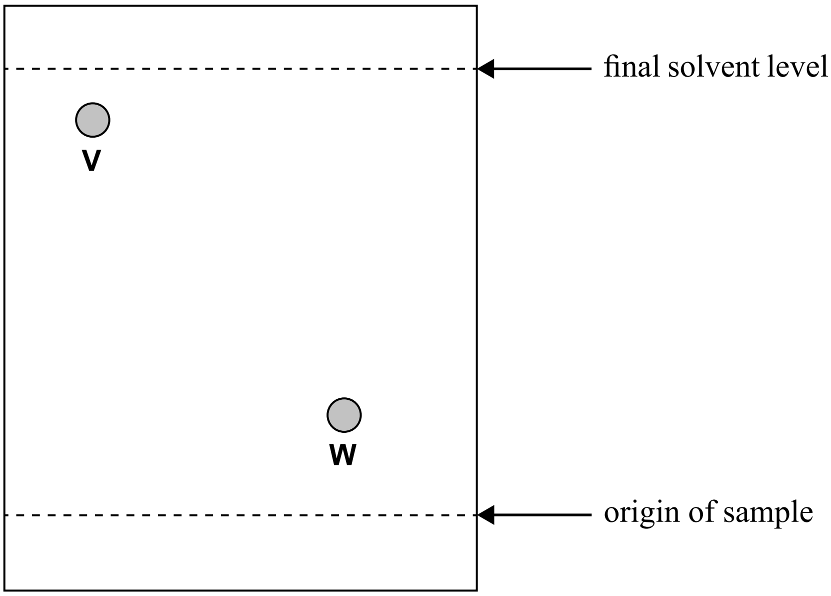
(Option B continues on the following page)

(Option B, question 7 continued)

(d) A separate experiment was done to determine the amino acid composition of maltase. A sample of the enzyme was hydrolysed into a mixture of its component amino acids. Paper chromatography and a locating agent were then used to try to identify the amino acids present in the mixture. The diagram below shows part of the chromatogram in which the positions of two amino acids, **V** and **W**, can be seen.



Amino acid	R_f
Lysine	0.14
Glutamine	0.26
Proline	0.41
Methionine	0.56
Leucine	0.73

Use the chromatogram and the data table to deduce the identity of **V** and **W** if possible. *[2]*

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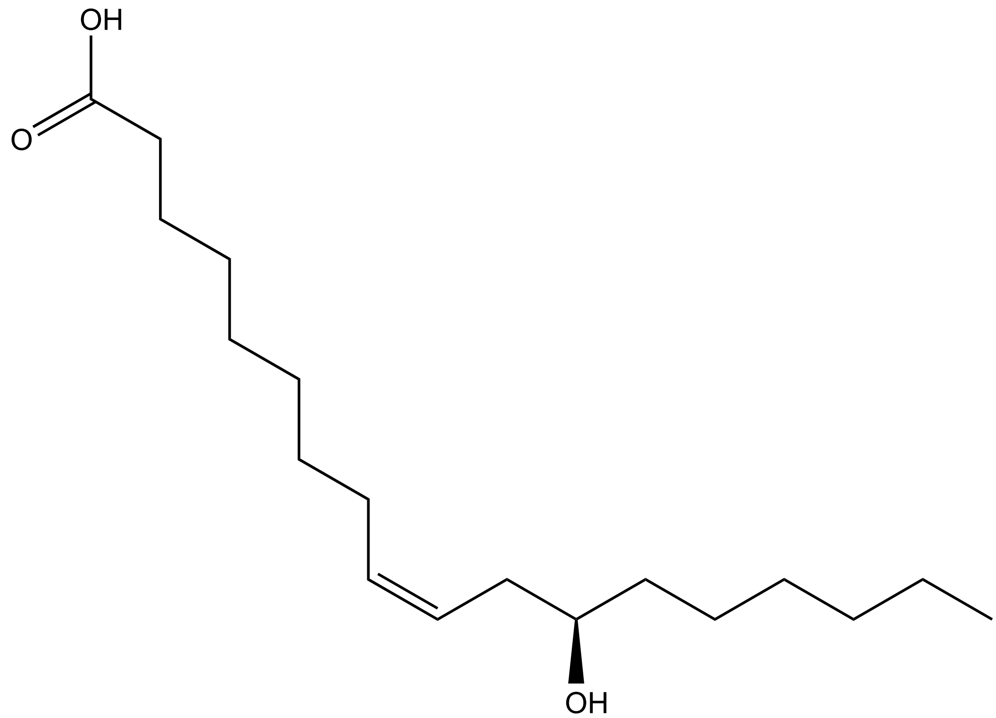
(Option B continues on the following page)

(Option B continued)

8. The castor plant is grown as a crop for its oil. Castor oil is mostly a triglyceride of the relatively rare fatty acid ricinoleic acid, whose structure is given below.



(a) State the molecular formula of ricinoleic acid. *[1]*

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(b) (i) Compare and contrast the structure of ricinoleic acid with stearic acid, whose structure is given in section 34 of the data booklet. *[3]*

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(Option B continues on the following page)

(Option B, question 8 continued)

(ii) State and explain how you would expect ricinoleic acid triglyceride to differ from stearic acid triglyceride in its tendency to undergo oxidative rancidity. *[2]*

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(c) The castor seed contains ricin, a toxic protein which is fatal in small doses. During the oil extraction process, the toxin is inactivated by heating.

(i) Outline why ricin loses its toxic effects on being heated. *[1]*

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(ii) Examine why many countries no longer harvest the castor plant but rely instead on imports of castor oil from other countries. *[2]*

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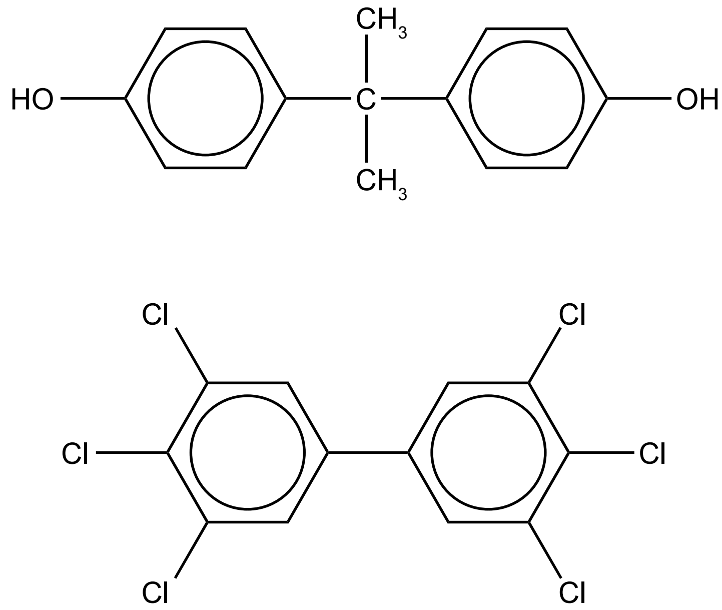
(Option B continues on the following page)

(Option B continued)

9. The figure below shows two examples of molecules known as xenoestrogens, a type of xenobiotic. They have effects on living organisms similar to those of the female hormone estrogen. These compounds are found in the environment and can be taken up by living organisms, where they may be stored in certain tissues.



(a) State what is meant by the term xenobiotic. *[1]*

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(b) With reference to their structures, outline why these xenobiotics are stored easily in animal fat. *[1]*

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(Option B continues on the following page)

(Option B, question 9 continued)

(c) One way to decrease the concentration of a xenobiotic in the environment is to develop a specific molecule, a "host", that can bind to it. The binding between the host and the xenobiotic forms a supramolecule.

State **three** types of association that may occur within the supramolecule between the host and the xenobiotic. *[1]*

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End of Option B

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Answers written on this page
will not be marked.

Option C — Energy

10. Plants convert solar energy into chemical energy. It would therefore be very convenient to use plant products, such as vegetable oils, directly as fuels for internal combustion engines.

(a) (i) Identify the major problem involved in using vegetable oils directly as a fuel in a conventional internal combustion engine. *[1]*

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(ii) Transesterification of the oil overcomes this problem. State the reagents required for this process. *[1]*

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(b) Plant products can also be converted to ethanol, which can be mixed with alkanes, such as octane, to produce a fuel. The table below gives some properties of these compounds.

Compound	**Molar mass / $g\,mol^{-1}$**	**Density / $g\,dm^{-3}$**	**ΔH_c / $kJ\,mol^{-1}$**	**Equation for combustion**
Ethanol	46.08	789	–1367	$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
Octane	114.26	703	–5470	$C_8H_{18}(l) + 12\frac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$

(i) State the name of the process by which ethanol can be produced from sugars. *[1]*

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(Option C continues on the following page)

(Option C, question 10 continued)

(ii) The energy density of ethanol is 23 400 kJ dm^{-3}. Use data from the table to determine the energy density of octane. *[1]*

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(iii) Use these results to outline why octane is the better fuel in vehicles. *[1]*

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(iv) Use data from the table to demonstrate that ethanol and octane give rise to similar carbon footprints. *[1]*

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(v) Outline why, even though they have similar carbon footprints, using ethanol has less impact on levels of atmospheric carbon dioxide. *[1]*

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(Option C continues on the following page)

(Option C continued)

11. Nuclear power is an energy source that does not involve fossil fuels. Current nuclear technology is dependent on fission reactions.

(a) Commercial nuclear power technology developed very rapidly between 1940 and 1970. Outline why this occurred. *[1]*

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(b) The equation for a typical nuclear fission reaction is:

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \, (\rightarrow {}^{236}_{92}\mathrm{U}) \rightarrow {}^{90}_{38}\mathrm{Sr} + {}^{136}_{54}\mathrm{Xe} + 10\,{}^{1}_{0}\mathrm{n}$$

The masses of the particles involved in this fission reaction are shown below.

Mass of neutron	=	1.00867 amu
Mass of U-235 nucleus	=	234.99333 amu
Mass of Xe-136 nucleus	=	135.90722 amu
Mass of Sr-90 nucleus	=	89.90774 amu

Using these data and information from sections 1 and 2 of the data booklet, determine the energy released when one uranium nucleus undergoes fission. *[3]*

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(Option C continues on the following page)

(Option C, question 11 continued)

(c) The half-lives of components of spent nuclear fuels range from a few years to more than 10,000 years. This means that while the radioactivity of nuclear waste initially decreases rapidly, some radioactivity remains for a very long time. Outline the storage of spent nuclear fuels in both the short and long term. *[2]*

Short term:

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Long term:

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(Option C continues on the following page)

(Option C continued)

12. Energy production presents many threats to the environment. One issue that has caused much controversy over recent years is the emission of greenhouse gases, which most scientists believe is a major cause of global warming.

(a) Explain how greenhouse gases affect the temperature of the Earth's surface. *[3]*

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(b) Explain the molecular changes that must occur in order for a molecule to absorb infrared light. *[2]*

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(Option C continues on the following page)

(Option C, question 12 continued)

(c) (i) Carbon dioxide and water vapour are the most abundant greenhouse gases. Identify **one** other greenhouse gas and a natural source of this compound. *[1]*

Greenhouse gas:

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Natural source:

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(ii) Even though water vapour is the more potent greenhouse gas, there is greater concern about the impact of carbon dioxide. Suggest why this is the case. *[1]*

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End of Option C

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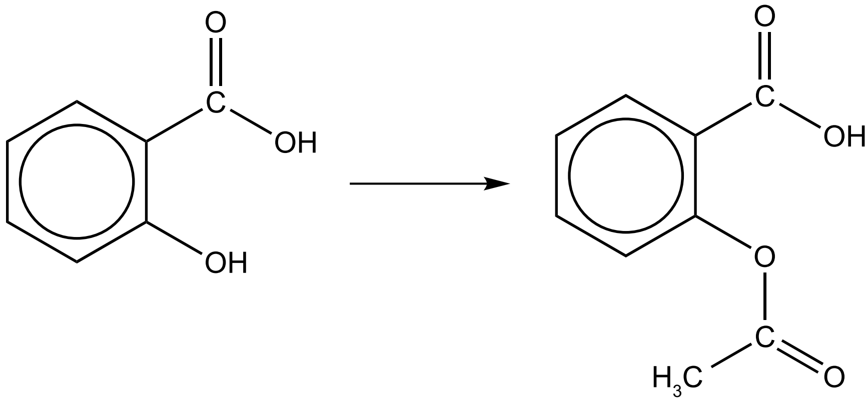
Answers written on this page
will not be marked.

Option D — Medicinal chemistry

13. Salicylic acid has been used to relieve pain and reduce fevers for centuries, although it can be irritating to the stomach. In the 1800s it was discovered that converting it into acetylsalicylic acid reduces the stomach irritation while still allowing it to be effective.



Salicylic acid   Acetylsalicylic acid (aspirin)

(a) Identify the type of reaction used to convert salicylic acid to acetylsalicylic acid. *[1]*

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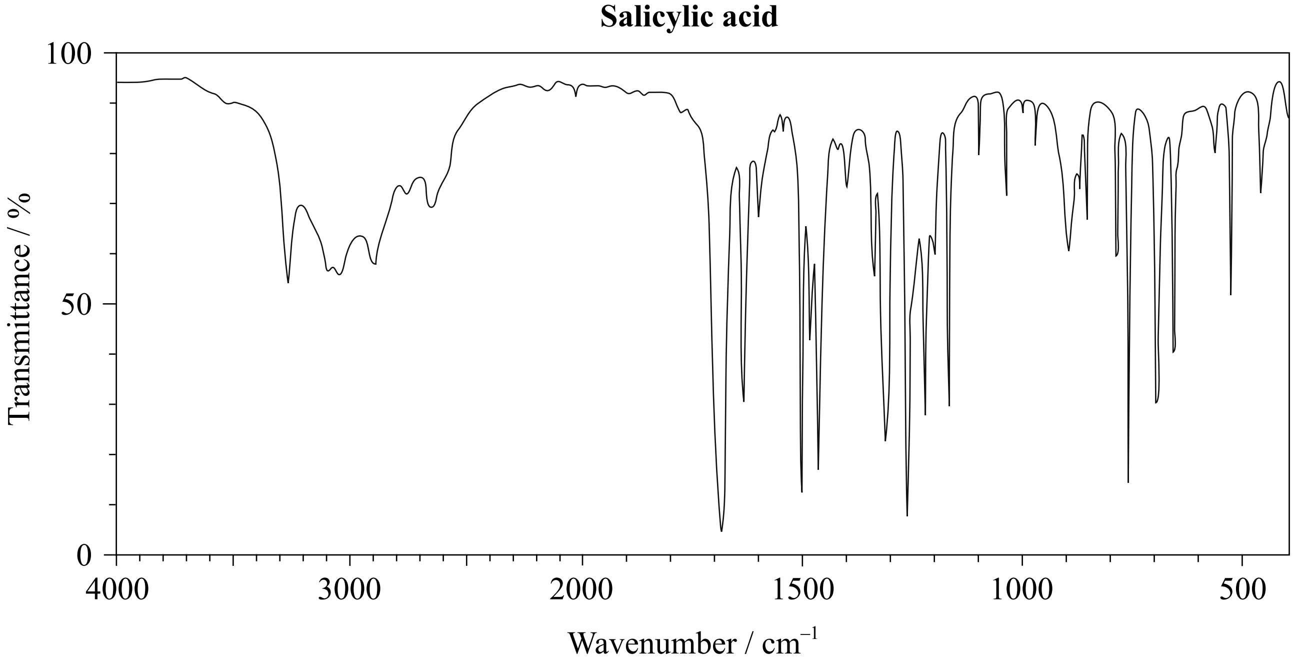
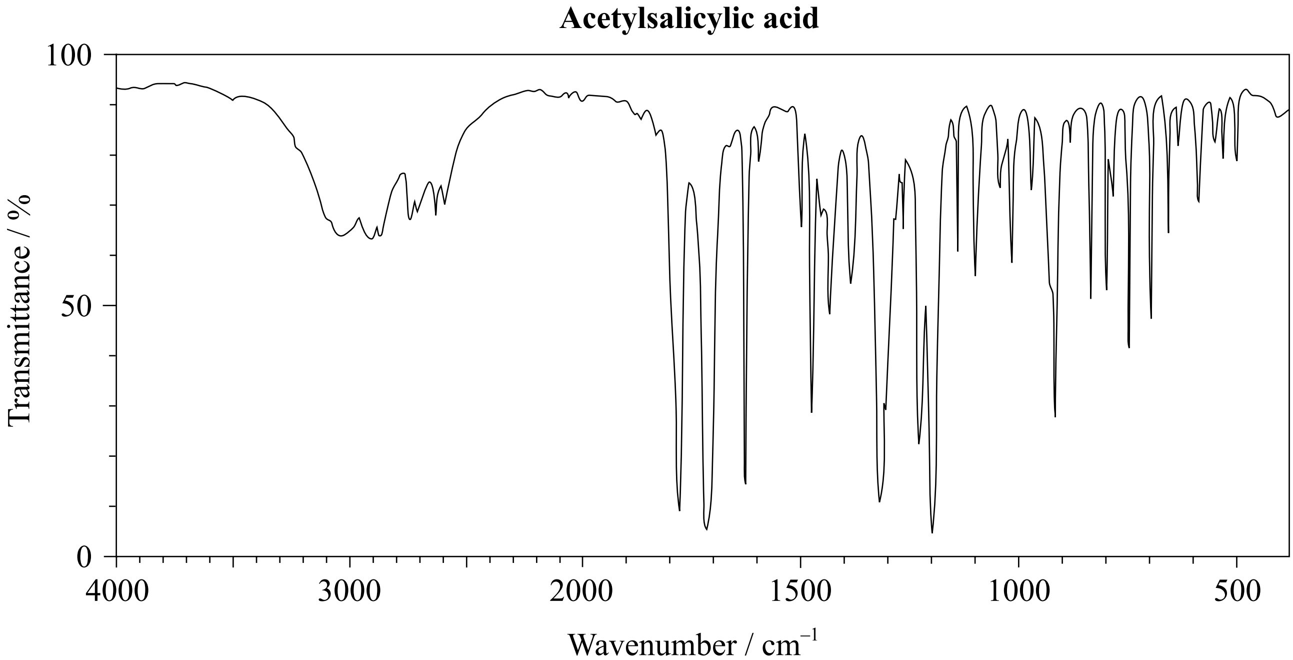
(Option D continues on the following page)

Turn over

(Option D, question 13 continued)

(b) The infrared (IR) spectra for salicylic acid and acetylsalicylic acid are shown below.





[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

(Option D continues on the following page)

(Option D, question 13 continued)

Using information from section 26 of the data booklet, compare and contrast the two spectra with respect to the bonds present. *[3]*

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(c) A modified version of aspirin is sometimes made by reacting it with a strong base, such as sodium hydroxide. Explain why this process can increase the bioavailability of the drug. *[3]*

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(Option D continues on the following page)

(Option D continued)

14. Recent advances in research into the viruses that cause flu have led to the production of two antiviral drugs, oseltamivir (Tamiflu®) and zanamivir (Relenza®).

(a) Outline why viruses are generally more difficult to target with drugs than bacteria. *[1]*

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(b) By reference to their molecular structures given in section 37 of the data booklet, state the formulas of **three** functional groups that are present in both oseltamivir and zanamivir and the formulas of **two** functional groups that are present in zanamivir only. *[3]*

Present in both:

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Present in zanamivir only:

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(c) Comment on how the widespread use of these drugs may lead to the spread of drug-resistant viruses. *[2]*

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(Option D continues on the following page)

(Option D, question 14 continued)

(d) Outline the general processes that should be followed to promote "green chemistry" in the manufacture of drugs such as oseltamivir and zanamivir. *[3]*

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(Option D continues on the following page)

(Option D continued)

15. Antacids help to neutralize excess hydrochloric acid produced by the stomach. The neutralizing power of an antacid can be defined as the amount in moles of hydrochloric acid that can be neutralized per gram of antacid.

(a) Formulate an equation to show the action of the antacid magnesium hydroxide. *[1]*

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(b) An antacid tablet with a mass of 0.200 g was added to 25.00 cm^3 of 0.125 mol dm^{-3} hydrochloric acid. After the reaction was complete, the excess acid required 5.00 cm^3 of 0.200 mol dm^{-3} sodium hydroxide to be neutralized. Determine the neutralizing power of the tablet. *[3]*

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End of Option D

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MARKSCHEME

SPECIMEN

CHEMISTRY

Standard Level

Paper 3

Subject Details: Chemistry SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[15 marks]** and all questions from **ONE** option in Section B **[20 marks]**.
Maximum total = **[35 marks]**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max"** written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by '***OR***' on the line between the alternatives. Either answer can be accepted.

7. Words in angled brackets **‹ ›** in the "Answers" column are not necessary to gain the mark.

8. Words that are <u>underlined</u> are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "ECF acceptable" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

14. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column, similarly, if the formula is specifically asked for, unless directed otherwise in the "Notes" column do not award a mark for a correct name.

15. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

16. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

SECTION A

Question			Answers	Notes	Total
1.	a	i	relative values ***OR*** compared with a standard ***OR*** not absolute measure ✓		**1**
	a	ii	high ODP for compounds with high Cl ***OR*** low ODP for compounds with less Cl ***OR*** zero ODP for compounds with no Cl ✓		**1**
	b		increasing atmospheric lifetime correlates with increasing GWP ✓ total contribution to global warming depends on length of time in atmosphere ***OR*** GWP depends on efficiency as greenhouse gas and atmospheric lifetime ✓	*Accept alternate answers based on sound scientific reasoning.*	**2**
	c	i	1,1,1,2-tetrafluoroethane ✓	*Allow without commas or dashes.*	**1**
	c	ii	$M(\text{CH}_2\text{FCF}_3) = (12.01\times 2) + (1.01\times 2) + (19.00\times 4) = 102.04 \langle \text{g mol}^{-1} \rangle$ ✓ $\Delta H(\text{condensation CH}_2\text{FCF}_3) = -[0.217\langle \text{kJ g}^{-1}\rangle \times 102.04\langle \text{g mol}^{-1}\rangle] = -22.1\langle \text{kJ mol}^{-1}\rangle$ ✓	*Award **[1 max]** for $\Delta H = 22.1\,kJ$*	**2**
	c	iii	atmospheric lifetime CO_2 much longer than CH_2FCF_3 ***OR*** after 100 years approx 30 % CO_2 still present whereas CH_2FCF_3 removed ✓ CO_2 from current emissions will continue to effect climate change/global warming far into the future ✓	*OWTTE*	**2**

Question			Answers	Notes	Total
2.	**a**		forgot to take account of water of crystallisation ***OR*** should have used 24.972 g ✓	*OWTTE*	**1**
	b		less uncertainty in the volume ***OR*** more precise ✓ takes into account volume change on dissolving ***OR*** concentration is for a given volume of solution not volume of solvent ✓		**2**
	c		filter ***OR*** centrifuge ✓ rinse (the solid) with water ✓ heat in an oven ***OR*** rinse with propanone/ethanol/volatile organic solvent and leave to evaporate ✓	*Award* ***[2]*** *for all 3,* ***[1]*** *for any 2.*	**2**
	d		taking a known mass of the solid to react directly with glucose ***OR*** not making the standard solution ✓	*OWTTE* *Accept any other valid answer based on sound scientific reasoning.*	**1**

SECTION B

Option A — Materials

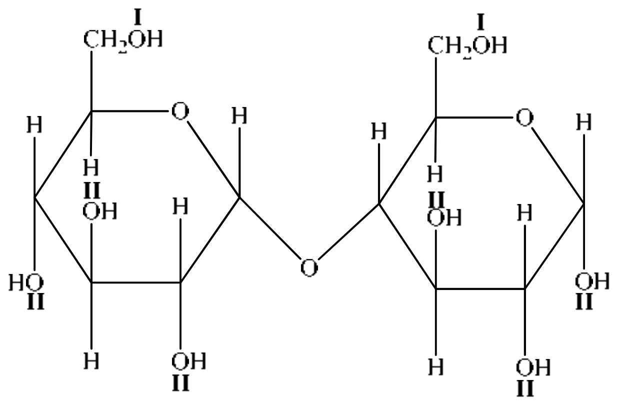
Question			Answers	Notes	Total
3.	**a**		rigid ***OR*** rod-shaped/long thin molecule ✓		**1**
	b	**i**	mixture of carbon containing compound and inert dilutant in gas/vapour phase ✓ passed over a heated metal catalyst ✓		**2**
	b	**ii**	(very) large surface area ✓		**1**

<table>
<tr><td>4.</td><td>a</td><td></td><td>
<table>
<tr><th>Compound</th><th>Magnesium oxide</th><th>Cobalt(II) oxide</th><th></th></tr>
<tr><td>Electronegativity difference</td><td>2.1</td><td>1.5</td><td>✓</td></tr>
<tr><td>Average electronegativity</td><td>2.35</td><td>2.65</td><td>✓</td></tr>
</table>
</td><td>Award [1] per correct row or column.</td><td>2</td></tr>
<tr><td></td><td>b</td><td></td><td>
<table>
<tr><th>Compound</th><th>Magnesium oxide</th><th>Cobalt(II) oxide</th><th></th></tr>
<tr><td>Bond type</td><td>Ionic</td><td>Polar covalent</td><td>✓</td></tr>
<tr><td>% covalent character</td><td>30 – 35</td><td>53 – 58</td><td>✓</td></tr>
</table>
</td><td>Award [1] per correct row or column.</td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
5.	a		positive argon ions and (free) electrons ✓		1
	b	i	mol Mg^{2+} = «$0.25 \times 10 \times 10^{-6}$ =» 2.5×10^{-6} «mol» ✓ mass Mg^{2+} = «$24.31 \times 2.5 \times 10^{-6}$ =» 6.08×10^{-5} g ✓		2
	b	ii	mass of solid too small to weigh accurately ✓ successive dilution of solution ***OR*** dilution of concentrated solution ✓	*OWTTE*	2
	b	iii	627 kcps **and** it lies inside of the calibrated region ***OR*** 627 kcps **and** 12 kcps lies outside of calibrated region ✓	*Accept other correct suggestions, for example “low values such as 12 kcps would have very high uncertainty”.*	1

Question			Answers	Notes	Total
6.	**a**		resin identification codes ✓ ensures uniformity for recycling ✓ ***OR*** addition/condensation ✓ classification into similar reaction types ✓ ***OR*** flexible ✓ direct towards appropriate uses ✓ ***OR*** brittle ✓ direct towards appropriate uses ✓	*OWTTE* *Accept "predict possible monomers". OWTTE* *Accept any other valid scientific classification with a justifiable scientific reason for* ***[2]****.*	**2**
	b		softens the polymer ✓ separates the polymer chains ***OR*** reduces intermolecular forces ✓		**2**
	c		all of the reagents end up in useful product ***OR*** atom economy is 100% ***OR*** there is no chemical waste ✓		**1**
	d		hydrogen chloride/HCl ***OR*** dioxin ✓		**1**

Option B — Biochemistry

Question			Answers	Notes	Total
7.	**a**		 ✓	*Award mark for a correctly placed **I** **and** a correctly placed **II**.* *Allow **II** placed on hemiacetal.*	**1**
	b	**i**	$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$ ✓		**1**
	b	**ii**	catabolism ✓	*Accept hydrolysis.*	**1**
	c		at X (low pH) enzyme/protein protonated/positively charged/cationic (so unable to bind effectively) ✓ at Y (optimum pH) enzyme maximally able to bind to substrate/maltose ✓ at Z (high pH) enzyme/protein deprotonated/negatively charged/anionic (so unable to bind effectively) ✓	*Award **[1 max]** for reference to denaturation/change in shape of active site without explanation in terms of changes in ionization.*	**3**
	d		R_f value $V = \frac{5.4}{5.9} = 0.91$ **and** R_f value $W = \frac{1.5}{5.9} = 0.25$ ✓ so W is glutamine (V cannot be identified) ✓		**2**

Question			Answers	Notes	Total
8.	**a**		$C_{18}H_{34}O_3$ ✓		**1**
	b	**i**	both have 18 carbon atoms ✓ both have COOH/carboxylic acid group ***OR*** both are fatty acids ✓ ricinoleic acid has a <u>carbon-carbon</u> double bond/C=C/‹mono›unsaturated whereas stearic acid has all single C–C bonds/saturated ✓ ricinoleic acid has an OH/hydroxyl group ‹in the chain› whereas stearic acid does not ✓	*Do not accept just acids in M2* *Any 3 for **[3 max]**.*	**3 max**
	b	**ii**	ricinoleic acid more likely to undergo oxidative rancidity ‹than stearic acid› ✓ <u>carbon-carbon</u> double bond/C=C can be oxidised ✓	*OWTTE*	**2**
	c	**i**	‹heating causes› denaturation ***OR*** ‹heating causes› loss of conformation ***OR*** ‹heating causes› change of shape ***OR*** ‹heating causes› inability to bind substrates ✓	*Do not accept inactivated.*	**1**
	c	**ii**	castor seeds contain toxins/ricin ***OR*** ingesting raw seeds can be fatal ✓ different health/safety standards in different countries ***OR*** richer countries exploit workers in less-developed/poorer countries ✓	*Accept alternate valid answers, such as economic considerations.*	**2**

Question			Answers	Notes	Total
9.	**a**		substance/chemical/compound found in organism not normally present ***OR*** compound foreign to living organism ✓	*Accept artificially synthesised/man-made compound in the environment/biosphere.*	**1**
	b		non-polar ***OR*** lipophilic ***OR*** structure based on phenyl/hydrocarbon ***OR*** hydrophobic interactions ***OR*** similar (non)polarity to fat ✓		**1**
	c		ionic bonds ✓ hydrogen bonds ✓ van der Waals’ forces ✓ hydrophobic interactions ✓	*Award **[1]** for any 3 correct answers.* *Accept alternate valid answers other than covalent bonding.*	**1 max**

Option C — Energy

Question			Answers	Notes	Total
10.	**a**	**i**	viscosity too high ✓		**1**
	a	**ii**	alcohol **and** (strong) acid ***OR*** base ✓	*Accept any specific alcohol (eg ethanol).*	**1**
	b	**i**	fermentation ✓		**1**
	b	**ii**	‹ $\frac{703 \times 5470}{114.26} =$ › 33700 ‹ kJ dm^{-3} › ✓		**1**
	b	**iii**	more energy from a given volume of fuel ✓	*Accept greater energy density.*	**1**
	b	**iv**	ethanol: $\frac{1367}{2} = 683.5\,\text{kJ mol}^{-1}$ **and** octane: $\frac{5470}{8} = 683.8\,\text{kJ mol}^{-1}$ ***OR*** mass of CO_2 produced in the release of 1000 kJ ethanol: $\frac{2 \times 44.01 \times 1000}{1367} = 64.4\,\text{g}$ **and** octane: $\frac{8 \times 44.01 \times 1000}{1367} = 64.4\,\text{g}$ ✓	*Accept other methods that show the amount carbon dioxide produced for the same heat energy output is the same for both fuels.*	**1**
	b	**v**	ethanol is a biofuel/produced from plant material ***OR*** growing plants absorbs carbon dioxide ✓		**1**

Question			Answers	Notes	Total
11.	**a**		nuclear power benefitted from the race to develop nuclear weapons ✓	*OWTTE* *Accept other valid explanations.*	**1**
	b		$\Delta m =$ ‹$234.99333 - 135.90722 - 89.907738 - [9 \times 1.00867] =$› 0.100342 ‹amu› ✓ $=$ ‹$0.100342 \times 1.66 \times 10^{-27}$ ‹kg› $=$› 1.67×10^{-28} ‹kg› ✓ $E =$ ‹$mc^2 = 1.67 \times 10^{-28} \times (3 \times 10^8)^2 =$› 1.50×10^{-11} ‹J› ✓	*Award* ***[3]*** *for correct final answer.*	**3**
	c		*Short term:* in cooling ponds ✓ *Long term:* vitrification ***OR*** underground in stable geological formations ✓		**2**

Question			Answers	Notes	Total
12.	**a**		incoming solar radiation is short wavelength ***OR*** incoming solar radiation is high frequency ***OR*** incoming solar radiation is high energy radiation ***OR*** incoming solar radiation is (UV radiation) ✓ radiation emitted (by the Earth's surface) is long wavelength ***OR*** radiation emitted (by the Earth's surface) is low frequency ***OR*** radiation emitted (by the Earth's surface) is low energy ***OR*** radiation emitted (by the Earth's surface) is IR radiation ✓ this energy is absorbed in the bonds of greenhouse gases ***OR*** the molecules vibrate when IR radiation is absorbed ✓ this energy is then re-radiated ‹some of it towards the surface of the Earth› ✓		**3 max**
	b		stretching ***OR*** bending ✓ causing a change in polarity/dipole moment ✓		**2**
	c	**i**	methane **and** anaerobic decomposition of organic matter ***OR*** digestion in animals ✓	*Accept other examples of greenhouse gases with correct* <u>*natural*</u> *sources.*	**1**
	c	**ii**	major sources of water vapour are natural rather than anthropogenic/due to humans ***OR*** levels of water vapour have remained almost constant whereas those of CO_2 have increased significantly in recent times ✓		**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
13.	**a**		esterification ***OR*** condensation ✓		**1**
	b		*Difference*: only spectrum for salicylic acid has ‹strong broad› peak from 3200–3600 cm^{-1} for OH ‹in alcohol/phenol› ✓ *Similarities*: both have ‹strong› peaks from 1050–1410 cm^{-1} for C–O ‹in alcohol/phenol› ✓ both have ‹strong› peaks from1700–1750 cm^{-1} for C=O ‹in carboxylic acid› ✓ both have ‹broad› peaks from 2500–3000 cm^{-1} for OH ‹in carboxylic acid› ✓ both have peaks from 2850–3090 cm^{-1} for C–H ✓	*Accept "acetylsalicylic acid has two peaks in the 1700–1800 cm^{-1} range due to 2 different C=O".* *Award **[2 max]** for two of the following similarities.*	**3 max**
	c		reaction with NaOH produces ‹ionic› salt ***OR*** $C_6H_4(OH)(COOH) + NaOH \rightarrow C_6H_4(OH)(COONa) + H_2O$ ✓ increases ‹aqueous› solubility ‹for transport/uptake› ✓ higher proportion of drug/dosage reaches target region/cells ✓		**3**

Question			Answers	Notes	Total
14.	**a**		lack cell structure ***OR*** exist within host cell ***OR*** mutate easily and frequently ✓		**1**
	b		*Present in both*: NH_2 ✓ CONH ✓ C=C ✓ COC ✓ *Present in zanamivir only*: COOH **and** OH ✓	*For similarities award **[2 max]** for any three correct, **[1 max]** for two correct, **[0]** for one correct.* *Accept C=N.*	**3 max**
	c		exposure of viruses to the drug favours resistant strains ✓ resistant strains difficult to treat ***OR*** drugs should be used only when required ‹not as prophylactic› ✓	*OWTTE*	**2**

(Question 14 continued)

Question			Answers	Notes	Total
	d		design chemicals to be less hazardous to health and environment ✓ use solvents/reagents that are less hazardous to the environment ✓ design ‹synthetic› processes that use less energy/materials ***OR*** design ‹synthetic› processes with high atom economy ✓ use renewable resources ***OR*** reuse/recycle materials ✓ treat waste to make less hazardous ✓ proper disposal of hazardous waste ✓		**3 max**

15.	**a**		$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$ ✓		**1**
	b		n(HCl added) = ‹0.02500 × 0.125 =› 0.00313 ‹mol› ✓ n(HCl unreacted with tablet) = n(NaOH) = 0.00500 × 0.200 = 0.00100 ‹mol HCl excess› n(HCl reacted with antacid) = ‹0.00313 – 0.00100 =› 0.00213 ‹mol› ✓ neutralizing power ‹ mol g^{-1} › = ‹$\frac{0.00213}{0.200}$ =› 0.011 ‹ mol HCl neutralized per g antacid› ✓		**3**

Diploma Programme

Chemistry guide

First assessment 2016

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Diploma Programme

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The International Baccalaureate Organization (known as the IB) offers four high-quality and challenging educational programmes for a worldwide community of schools, aiming to create a better, more peaceful world. This publication is one of a range of materials produced to support these programmes.

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IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

As IB learners we strive to be:

INQUIRERS
We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life.

KNOWLEDGEABLE
We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance.

THINKERS
We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions.

COMMUNICATORS
We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups.

PRINCIPLED
We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences.

OPEN-MINDED
We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.

CARING
We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.

RISK-TAKERS
We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change.

BALANCED
We understand the importance of balancing different aspects of our lives—intellectual, physical, and emotional—to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live.

REFLECTIVE
We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.

The IB learner profile represents 10 attributes valued by IB World Schools. We believe these attributes, and others like them, can help individuals and groups become responsible members of local, national and global communities.

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Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This guide can be found on the subject page of the online curriculum centre (OCC) at http://occ.ibo.org, a password-protected IB website designed to support IB teachers. It can also be purchased from the IB store at http://store.ibo.org.

Additional resources

Additional publications such as teacher support materials, subject reports, internal assessment guidance and grade descriptors can also be found on the OCC. Past examination papers as well as markschemes can be purchased from the IB store.

Teachers are encouraged to check the OCC for additional resources created or used by other teachers. Teachers can provide details of useful resources, for example: websites, books, videos, journals or teaching ideas.

Acknowledgment

The IB wishes to thank the educators and associated schools for generously contributing time and resources to the production of this guide.

First assessment 2016

The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme model

The course is presented as six academic areas enclosing a central core (see figure 1). It encourages the concurrent study of a broad range of academic areas. Students study two modern languages (or a modern language and a classical language), a humanities or social science subject, a science, mathematics and one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.

Figure 1
Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can, instead of an arts subject, choose two subjects from another area. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers.

The core of the Diploma Programme model

All Diploma Programme students participate in the three course elements that make up the core of the model. Theory of knowledge (TOK) is a course that is fundamentally about critical thinking and inquiry into the process of knowing rather than about learning a specific body of knowledge. The TOK course examines the nature of knowledge and how we know what we claim to know. It does this by encouraging students to analyse knowledge claims and explore questions about the construction of knowledge. The task of TOK is to emphasize connections between areas of shared knowledge and link them to personal knowledge in such a way that an individual becomes more aware of his or her own perspectives and how they might differ from others.

Creativity, action, service (CAS) is at the heart of the Diploma Programme. The emphasis in CAS is on helping students to develop their own identities, in accordance with the ethical principles embodied in the IB mission statement and the IB learner profile. It involves students in a range of activities alongside their academic studies throughout the Diploma Programme. The three strands of CAS are Creativity (arts and other experiences that involve creative thinking), Action (physical exertion contributing to a healthy lifestyle) and Service (an unpaid and voluntary exchange that has a learning benefit for the student). Possibly, more than any other component in the Diploma Programme, CAS contributes to the IB's mission to create a better and more peaceful world through intercultural understanding and respect.

The extended essay, including the world studies extended essay, offers the opportunity for IB students to investigate a topic of special interest, in the form of a 4,000-word piece of independent research. The area of research undertaken is chosen from one of the students' Diploma Programme subjects, or in the case of the interdisciplinary world studies essay, two subjects, and acquaints them with the independent research and writing skills expected at university. This leads to a major piece of formally presented, structured writing, in which ideas and findings are communicated in a reasoned and coherent manner, appropriate to the subject or subjects chosen. It is intended to promote high-level research and writing skills, intellectual discovery and creativity. As an authentic learning experience it provides students with an opportunity to engage in personal research on a topic of choice, under the guidance of a supervisor.

Approaches to teaching and approaches to learning

Approaches to teaching and learning across the Diploma Programme refer to deliberate strategies, skills and attitudes which permeate the teaching and learning environment. These approaches and tools, intrinsically linked with the learner profile attributes, enhance student learning and assist student preparation for the Diploma Programme assessment and beyond. The aims of approaches to teaching and learning in the Diploma Programme are to:

- empower teachers as teachers of learners as well as teachers of content
- empower teachers to create clearer strategies for facilitating learning experiences in which students are more meaningfully engaged in structured inquiry and greater critical and creative thinking
- promote both the aims of individual subjects (making them more than course aspirations) and linking previously isolated knowledge (concurrency of learning)
- encourage students to develop an explicit variety of skills that will equip them to continue to be actively engaged in learning after they leave school, and to help them not only obtain university admission through better grades but also prepare for success during tertiary education and beyond
- enhance further the coherence and relevance of the students' Diploma Programme experience
- allow schools to identify the distinctive nature of an IB Diploma Programme education, with its blend of idealism and practicality.

The five approaches to learning (developing thinking skills, social skills, communication skills, self-management skills and research skills) along with the six approaches to teaching (teaching that is inquiry-based, conceptually focused, contextualized, collaborative, differentiated and informed by assessment) encompass the key values and principles that underpin IB pedagogy.

The IB mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IB, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

Academic honesty

Academic honesty in the Diploma Programme is a set of values and behaviours informed by the attributes of the learner profile. In teaching, learning and assessment, academic honesty serves to promote personal integrity, engender respect for the integrity of others and their work, and ensure that all students have an equal opportunity to demonstrate the knowledge and skills they acquire during their studies.

All coursework—including work submitted for assessment—is to be authentic, based on the student's individual and original ideas with the ideas and work of others fully acknowledged. Assessment tasks that require teachers to provide guidance to students or that require students to work collaboratively must be completed in full compliance with the detailed guidelines provided by the IB for the relevant subjects.

For further information on academic honesty in the IB and the Diploma Programme, please consult the IB publications *Academic honesty* (2011), *The Diploma Programme: From principles into practice* (2009) and *General regulations: Diploma Programme* (2011). Specific information regarding academic honesty as it pertains to external and internal assessment components of this Diploma Programme subject can be found in this guide.

Acknowledging the ideas or work of another person

Coordinators and teachers are reminded that candidates must acknowledge all sources used in work submitted for assessment. The following is intended as a clarification of this requirement.

Diploma Programme candidates submit work for assessment in a variety of media that may include audio-visual material, text, graphs, images and/or data published in print or electronic sources. If a candidate uses the work or ideas of another person the candidate must acknowledge the source using a standard style of referencing in a consistent manner. A candidate's failure to acknowledge a source will be investigated by the IB as a potential breach of regulations that may result in a penalty imposed by the IB final award committee.

The IB does not prescribe which style(s) of referencing or in-text citation should be used by candidates; this is left to the discretion of appropriate faculty/staff in the candidate's school. The wide range of subjects, three response languages and the diversity of referencing styles make it impractical and restrictive to insist on particular styles. In practice, certain styles may prove most commonly used, but schools are free to choose a style that is appropriate for the subject concerned and the language in which candidates' work is written. Regardless of the reference style adopted by the school for a given subject, it is expected that the minimum information given includes: name of author, date of publication, title of source, and page numbers as applicable.

Candidates are expected to use a standard style and use it consistently so that credit is given to all sources used, including sources that have been paraphrased or summarized. When writing text candidates must clearly distinguish between their words and those of others by the use of quotation marks (or other method, such as indentation) followed by an appropriate citation that denotes an entry in the bibliography. If an electronic source is cited, the date of access must be indicated. Candidates are not expected to show faultless expertise in referencing, but are expected to demonstrate that all sources have been acknowledged. Candidates must be advised that audio-visual material, text, graphs, images and/or data published in print or in electronic sources that is not their own must also attribute the source. Again, an appropriate style of referencing/citation must be used.

Learning diversity and learning support requirements

Schools must ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity in the International Baccalaureate programmes: Special educational needs within the IB programmes*.

Nature of science

The Nature of science (NOS) is an overarching theme in the biology, chemistry and physics courses. This section, titled Nature of science, is in the biology, chemistry and physics guides to support teachers in their understanding of what is meant by the nature of science. The "Nature of science" section of the guide provides a comprehensive account of the nature of science in the 21st century. It will not be possible to cover in this document all the themes in detail in the three science courses, either for teaching or assessment.

It has a paragraph structure (1.1, 1.2, etc) to link the significant points made to the syllabus (landscape pages) references on the NOS. The NOS parts in the subject-specific sections of the guide are examples of a particular understanding. The NOS statement(s) above every sub-topic outline how one or more of the NOS themes can be exemplified through the understandings, applications and skills in that sub-topic. These are not a repeat of the NOS statements found below but an elaboration of them in a specific context. See the section on "Format of the syllabus".

Technology

Although this section is about the nature of science, the interpretation of the word technology is important, and the role of technology emerging from and contributing to science needs to be clarified. In today's world, the words *science* and *technology* are often used interchangeably, however, historically this is not the case. Technology emerged before science, and materials were used to produce useful and decorative artefacts long before there was an understanding of why materials had different properties that could be used for different purposes. In the modern world the reverse is the case: an understanding of the underlying science is the basis for technological developments. These new technologies in their turn drive developments in science.

Despite their mutual dependence they are based on different values: science on evidence, rationality and the quest for deeper understanding; technology on the practical, the appropriate and the useful with an increasingly important emphasis on sustainability.

1. What is science and what is the scientific endeavour?

1.1. The underlying assumption of science is that the universe has an independent, external reality accessible to human senses and amenable to human reason.

1.2. Pure science aims to come to a common understanding of this external universe; applied science and engineering develop technologies that result in new processes and products. However, the boundaries between these fields are fuzzy.

1.3. Scientists use a wide variety of methodologies which, taken together, make up the process of science. There is no single "scientific method". Scientists have used, and do use, different methods at different times to build up their knowledge and ideas but they have a common understanding about what makes them all scientifically valid.

1.4. This is an exciting and challenging adventure involving much creativity and imagination as well as exacting and detailed thinking and application. Scientists also have to be ready for unplanned, surprising, accidental discoveries. The history of science shows this is a very common occurrence.

1.5. Many scientific discoveries have involved flashes of intuition and many have come from speculation or simple curiosity about particular phenomena.

1.6. Scientists have a common terminology and a common reasoning process, which involves using deductive and inductive logic through analogies and generalizations. They share mathematics, the language of science, as a powerful tool. Indeed, some scientific explanations only exist in mathematical form.

1.7. Scientists must adopt a skeptical attitude to claims. This does not mean that they disbelieve everything, but rather that they suspend judgment until they have a good reason to believe a claim to be true or false. Such reasons are based on evidence and argument.

1.8. The importance of evidence is a fundamental common understanding. Evidence can be obtained by observation or experiment. It can be gathered by human senses, primarily sight, but much modern science is carried out using instrumentation and sensors that can gather information remotely and automatically in areas that are too small, or too far away, or otherwise beyond human sense perception. Improved instrumentation and new technology have often been the drivers for new discoveries. Observations followed by analysis and deduction led to the Big Bang theory of the origin of the universe and to the theory of evolution by natural selection. In these cases, no controlled experiments were possible. Disciplines such as geology and astronomy rely strongly on collecting data in the field, but all disciplines use observation to collect evidence to some extent. Experimentation in a controlled environment, generally in laboratories, is the other way of obtaining evidence in the form of data, and there are many conventions and understandings as to how this is to be achieved.

1.9. This evidence is used to develop theories, generalize from data to form laws and propose hypotheses. These theories and hypotheses are used to make predictions that can be tested. In this way theories can be supported or opposed and can be modified or replaced by new theories.

1.10. Models, some simple, some very complex, based on theoretical understanding, are developed to explain processes that may not be observable. Computer-based mathematical models are used to make testable predictions, which can be especially useful when experimentation is not possible. Models tested against experiments or data from observations may prove inadequate, in which case they may be modified or replaced by new models.

1.11. The outcomes of experiments, the insights provided by modelling and observations of the natural world may be used as further evidence for a claim.

1.12. The growth in computing power has made modelling much more powerful. Models, usually mathematical, are now used to derive new understandings when no experiments are possible (and sometimes when they are). This dynamic modelling of complex situations involving large amounts of data, a large number of variables and complex and lengthy calculations is only possible as a result of increased computing power. Modelling of the Earth's climate, for example, is used to predict or make a range of projections of future climatic conditions. A range of different models have been developed in this field and results from different models have been compared to see which models are most accurate. Models can sometimes be tested by using data from the past and used to see if they can predict the present situation. If a model passes this test, we gain confidence in its accuracy.

1.13. Both the ideas and the processes of science can only occur in a human context. Science is carried out by a community of people from a wide variety of backgrounds and traditions, and this has clearly influenced the way science has proceeded at different times. It is important to understand, however, that to do science is to be involved in a community of inquiry with certain common principles, methodologies, understandings and processes.

2. The understanding of science

2.1. Theories, laws and hypotheses are concepts used by scientists. Though these concepts are connected, there is no progression from one to the other. These words have a special meaning in science and it is important to distinguish these from their everyday use.

2.2. Theories are themselves integrated, comprehensive models of how the universe, or parts of it, work. A theory can incorporate facts and laws and tested hypotheses. Predictions can be made from the theories and these can be tested in experiments or by careful observations. Examples are the germ theory of disease or atomic theory.

2.3. Theories generally accommodate the assumptions and premises of other theories, creating a consistent understanding across a range of phenomena and disciplines. Occasionally, however, a new theory will radically change how essential concepts are understood or framed, impacting other theories and causing what is sometimes called a “paradigm shift” in science. One of the most famous paradigm shifts in science occurred when our idea of time changed from an absolute frame of reference to an observer-dependent frame of reference within Einstein’s theory of relativity. Darwin’s theory of evolution by natural selection also changed our understanding of life on Earth.

2.4. Laws are descriptive, normative statements derived from observations of regular patterns of behaviour. They are generally mathematical in form and can be used to calculate outcomes and to make predictions. Like theories and hypotheses, laws cannot be proven. Scientific laws may have exceptions and may be modified or rejected based on new evidence. Laws do not necessarily explain a phenomenon. For example, Newton’s law of universal gravitation tells us that the force between two masses is inversely proportional to the square of the distance between them, and allows us to calculate the force between masses at any distance apart, but it does not explain why masses attract each other. Also, note that the term law has been used in different ways in science, and whether a particular idea is called a law may be partly a result of the discipline and time period at which it was developed.

2.5. Scientists sometimes form hypotheses—explanatory statements about the world that could be true or false, and which often suggest a causal relationship or a correlation between factors. Hypotheses can be tested by both experiments and observations of the natural world and can be supported or opposed.

2.6. To be scientific, an idea (for example, a theory or hypothesis) must focus on the natural world and natural explanations and must be testable. Scientists strive to develop hypotheses and theories that are compatible with accepted principles and that simplify and unify existing ideas.

2.7. The principle of Occam’s razor is used as a guide to developing a theory. The theory should be as simple as possible while maximizing explanatory power.

2.8. The ideas of correlation and cause are very important in science. A correlation is a statistical link or association between one variable and another. A correlation can be positive or negative and a correlation coefficient can be calculated that will have a value between +1, 0 and -1. A strong correlation (positive or negative) between one factor and another suggests some sort of causal relationship between the two factors but more evidence is usually required before scientists accept the idea of a causal relationship. To establish a causal relationship, ie one factor causing another, scientists need to have a plausible scientific mechanism linking the factors. This strengthens the case that one causes the other, eg smoking and lung cancer. This mechanism can be tested in experiments.

2.9. The ideal situation is to investigate the relationship between one factor and another while controlling all other factors in an experimental setting; however, this is often impossible and scientists, especially in biology and medicine, use sampling, cohort studies and case control studies to strengthen their understanding of causation when experiments (such as double blind tests and clinical trials) are not possible. Epidemiology in the field of medicine involves the statistical analysis of data to discover possible correlations when little established scientific knowledge is available or the circumstances are too difficult to control entirely. Here, as in other fields, mathematical analysis of probability also plays a role.

3. The objectivity of science

3.1. Data is the lifeblood of scientists and may be qualitative or quantitative. It can be obtained purely from observations or from specifically designed experiments, remotely using electronic sensors or by direct measurement. The best data for making accurate and precise descriptions and predictions is often quantitative and amenable to mathematical analysis. Scientists analyse data and look for patterns, trends and discrepancies, attempting to discover relationships and establish causal links. This is not always possible, so identifying and classifying observations and artefacts (eg types of galaxies or fossils) is still an important aspect of scientific work.

3.2. Taking repeated measurements and large numbers of readings can improve reliability in data collection. Data can be presented in a variety of formats such as linear and logarithmic graphs that can be analysed for, say, direct or inverse proportion or for power relationships.

3.3. Scientists need to be aware of random errors and systematic errors, and use techniques such as error bars and lines of best fit on graphs to portray the data as realistically and honestly as possible. There is a need to consider whether outlying data points should be discarded or not.

3.4. Scientists need to understand the difference between errors and uncertainties, accuracy and precision, and need to understand and use the mathematical ideas of average, mean, mode, median, etc. Statistical methods such as standard deviation and chi-squared tests are often used. It is important to be able to assess how accurate a result is. A key part of the training and skill of scientists is in being able to decide which technique is appropriate in different circumstances.

3.5. It is also very important for scientists to be aware of the cognitive biases that may impact experimental design and interpretation. The confirmation bias, for example, is a well-documented cognitive bias that urges us to find reasons to reject data that is unexpected or does not conform to our expectations or desires, and to perhaps too readily accept data that agrees with these expectations or desires. The processes and methodologies of science are largely designed to account for these biases. However, care must always be taken to avoid succumbing to them.

3.6. Although scientists cannot ever be certain that a result or finding is correct, we know that some scientific results are very close to certainty. Scientists often speak of "levels of confidence" when discussing outcomes. The discovery of the existence of a Higgs boson is such an example of a "level of confidence". This particle may never be directly observable, but to establish its "existence" particle physicists had to pass the self-imposed definition of what can be regarded as a discovery—the 5-sigma "level of certainty"—or about a 0.00003% chance that the effect is not real based on experimental evidence.

3.7. In recent decades, the growth in computing power, sensor technology and networks has allowed scientists to collect large amounts of data. Streams of data are downloaded continuously from many sources such as remote sensing satellites and space probes and large amounts of data are generated in gene sequencing machines. Experiments in CERN's Large Hadron Collider regularly produce 23 petabytes of data per second, which is equivalent to 13.3 years of high definition TV content per second.

3.8. Research involves analysing large amounts of this data, stored in databases, looking for patterns and unique events. This has to be done using software which is generally written by the scientists involved. The data and the software may not be published with the scientific results but would be made generally available to other researchers.

4. The human face of science

4.1. Science is highly collaborative and the scientific community is composed of people working in science, engineering and technology. It is common to work in teams from many disciplines so that different areas of expertise and specializations can contribute to a common goal that is beyond one scientific field. It is also the case that how a problem is framed in the paradigm of one discipline might limit possible solutions, so framing problems using a variety of perspectives, in which new solutions are possible, can be extremely useful.

4.2. Teamwork of this sort takes place with the common understanding that science should be open-minded and independent of religion, culture, politics, nationality, age and gender. Science involves the free global interchange of information and ideas. Of course, individual scientists are human and may have biases and prejudices, but the institutions, practices and methodologies of science help keep the scientific endeavour as a whole unbiased.

4.3. As well as collaborating on the exchange of results, scientists work on a daily basis in collaborative groups on a small and large scale within and between disciplines, laboratories, organizations and countries, facilitated even more by virtual communication. Examples of large-scale collaboration include:

- The Manhattan project, the aim of which was to build and test an atomic bomb. It eventually employed more than 130,000 people and resulted in the creation of multiple production and research sites that operated in secret, culminating in the dropping of two atomic bombs on Hiroshima and Nagasaki.
- The Human Genome Project (HGP), which was an international scientific research project set up to map the human genome. The $3-billion project beginning in 1990 produced a draft of the genome in 2000. The sequence of the DNA is stored in databases available to anyone on the internet.
- The IPCC (Intergovernmental Panel on Climate Change), organized under the auspices of The United Nations, is officially composed of about 2,500 scientists. They produce reports summarizing the work of many more scientists from all around the world.
- CERN, the European Organization for Nuclear Research, an international organization set up in 1954, is the world’s largest particle physics laboratory. The laboratory, situated in Geneva, employs about 2,400 people and shares results with 10,000 scientists and engineers covering over 100 nationalities from 600 or more universities and research facilities.

All the above examples are controversial to some degree and have aroused emotions amongst scientists and the public.

4.4. Scientists spend a considerable amount of time reading the published results of other scientists. They publish their own results in scientific journals after a process called peer review. This is when the work of a scientist or, more usually, a team of scientists is anonymously and independently reviewed by several scientists working in the same field who decide if the research methodologies are sound and if the work represents a new contribution to knowledge in that field. They also attend conferences to make presentations and display posters of their work. Publication of peer-reviewed journals on the internet has increased the efficiency with which the scientific literature can be searched and accessed. There are a large number of national and international organizations for scientists working in specialized areas within subjects.

4.5. Scientists often work in areas, or produce findings, that have significant ethical and political implications. These areas include cloning, genetic engineering of food and organisms, stem cell and reproductive technologies, nuclear power, weapons development (nuclear, chemical and biological), transplantation of tissue and organs and in areas that involve testing on animals (see *IB animal experimentation policy*). There are also questions involving intellectual property rights and the free exchange of information that may impact significantly on a society. Science is undertaken in universities, commercial companies, government organizations, defence agencies and international organizations. Questions of patents and intellectual property rights arise when work is done in a protected environment.

4.6. The integrity and honest representation of data is paramount in science—results should not be fixed or manipulated or doctored. To help ensure academic honesty and guard against plagiarism, all sources are quoted and appropriate acknowledgment made of help or support. Peer review and the scrutiny and skepticism of the scientific community also help achieve these goals.

4.7. All science has to be funded and the source of the funding is crucial in decisions regarding the type of research to be conducted. Funding from governments and charitable foundations is sometimes for pure research with no obvious direct benefit to anyone whereas funding from private companies is often for applied research to produce a particular product or technology. Political and economic factors often determine the nature and extent of the funding. Scientists often have to spend time applying for research grants and have to make a case for what they want to research.

4.8. Science has been used to solve many problems and improve man's lot, but it has also been used in morally questionable ways and in ways that inadvertently caused problems. Advances in sanitation, clean water supplies and hygiene led to significant decreases in death rates but without compensating decreases in birth rates this led to huge population increases with all the problems of resources, energy and food supplies that entails. Ethical discussions, risk-benefit analyses, risk assessment and the precautionary principle are all parts of the scientific way of addressing the common good.

5. Scientific literacy and the public understanding of science

5.1. An understanding of the nature of science is vital when society needs to make decisions involving scientific findings and issues. How does the public judge? It may not be possible to make judgments based on the public's direct understanding of a science, but important questions can be asked about whether scientific processes were followed and scientists have a role in answering such questions.

5.2. As experts in their particular fields, scientists are well placed to explain to the public their issues and findings. Outside their specializations, they may be no more qualified than ordinary citizens to advise others on scientific issues, although their understanding of the processes of science can help them to make personal decisions and to educate the public as to whether claims are scientifically credible.

5.3. As well as comprising knowledge of how scientists work and think scientific literacy involves being aware of faulty reasoning. There are many cognitive biases/fallacies of reasoning to which people are susceptible (including scientists) and these need to be corrected whenever possible. Examples of these are the confirmation bias, hasty generalizations, *post hoc ergo propter hoc* (false cause), the straw man fallacy, redefinition (moving the goal posts), the appeal to tradition, false authority and the accumulation of anecdotes being regarded as evidence.

5.4. When such biases and fallacies are not properly managed or corrected, or when the processes and checks and balances of science are ignored or misapplied, the result is pseudoscience. Pseudoscience is the term applied to those beliefs and practices which claim to be scientific but do not meet or follow the standards of proper scientific methodologies, ie they lack supporting evidence or a theoretical framework, are not always testable and hence falsifiable, are expressed in a non-rigorous or unclear manner and often fail to be supported by scientific testing.

5.5. Another key issue is the use of appropriate terminology. Words that scientists agree on as being scientific terms will often have a different meaning in everyday life and scientific discourse with the public needs to take this into account. For example, a theory in everyday use means a hunch or speculation, but in science an accepted theory is a scientific idea that has produced predictions that have been thoroughly tested in many different ways. An aerosol is just a spray can to the general public, but in science it is a suspension of solid or liquid particles in a gas.

5.6. Whatever the field of science—whether it is in pure research, applied research or in engineering new technology—there is boundless scope for creative and imaginative thinking. Science has achieved a great deal but there are many, many unanswered questions to challenge future scientists.

The flow chart below is part of an interactive flow chart showing the scientific process of inquiry in practice. The interactive version can be found at "How science works: The flowchart". Understanding Science. University of California Museum of Paleontology. 1 February 2013 <http://undsci.berkeley.edu/article/scienceflowchart>.

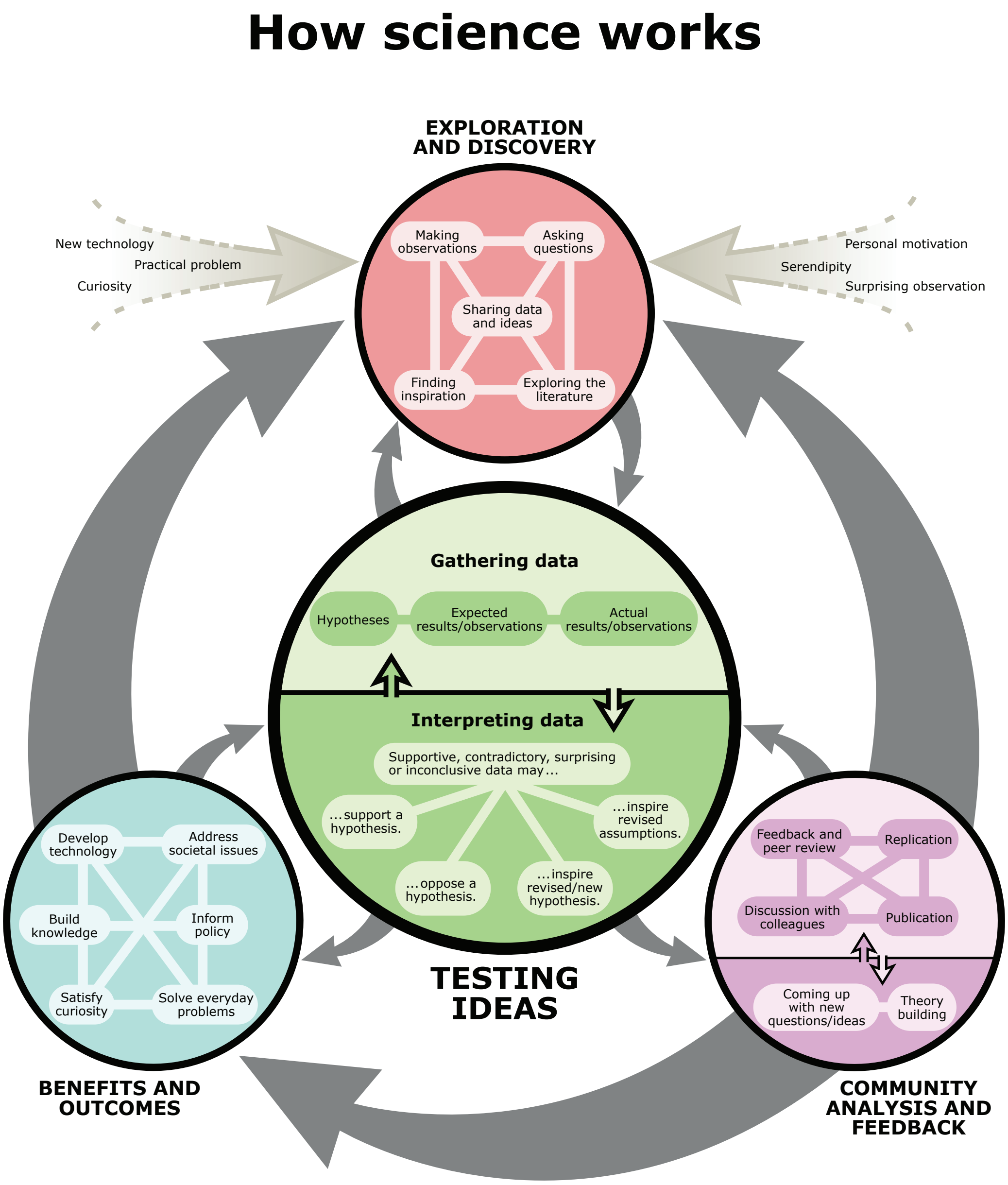


Figure 2

Pathways to scientific discovery

Nature of chemistry

Chemistry is an experimental science that combines academic study with the acquisition of practical and investigational skills. It is often called the central science, as chemical principles underpin both the physical environment in which we live and all biological systems. Apart from being a subject worthy of study in its own right, chemistry is a prerequisite for many other courses in higher education, such as medicine, biological science and environmental science, and serves as useful preparation for employment.

Earth, water, air and fire are often said to be the four classical elements. They have connections with Hinduism and Buddhism. The Greek philosopher Plato was the first to call these entities elements. The study of chemistry has changed dramatically from its origins in the early days of alchemists, who had as their quest the transmutation of common metals into gold. Although today alchemists are not regarded as being true scientists, modern chemistry has the study of alchemy as its roots. Alchemists were among the first to develop strict experimentation processes and laboratory techniques. Robert Boyle, often credited with being the father of modern chemistry, began experimenting as an alchemist.

Despite the exciting and extraordinary development of ideas throughout the history of chemistry, certain things have remained unchanged. Observations remain essential at the very core of chemistry, and this sometimes requires decisions about what to look for. The scientific processes carried out by the most eminent scientists in the past are the same ones followed by working chemists today and, crucially, are also accessible to students in schools. The body of scientific knowledge has grown in size and complexity, and the tools and skills of theoretical and experimental chemistry have become so specialized, that it is difficult (if not impossible) to be highly proficient in both areas. While students should be aware of this, they should also know that the free and rapid interplay of theoretical ideas and experimental results in the public scientific literature maintains the crucial link between these fields.

The Diploma Programme chemistry course includes the essential principles of the subject but also, through selection of an option, allows teachers some flexibility to tailor the course to meet the needs of their students. The course is available at both standard level (SL) and higher level (HL), and therefore accommodates students who wish to study chemistry as their major subject in higher education and those who do not.

At the school level both theory and experiments should be undertaken by all students. They should complement one another naturally, as they do in the wider scientific community. The Diploma Programme chemistry course allows students to develop traditional practical skills and techniques and to increase facility in the use of mathematics, which is the language of science. It also allows students to develop interpersonal skills, and digital technology skills, which are essential in 21st century scientific endeavour and are important life-enhancing, transferable skills in their own right.

Teaching approach

There are a variety of approaches to the teaching of chemistry. By its very nature, chemistry lends itself to an experimental approach, and it is expected that this will be reflected throughout the course.

The order in which the syllabus is arranged is **not** the order in which it should be taught, and it is up to individual teachers to decide on an arrangement that suits their circumstances. Sections of the option material may be taught within the core or the additional higher level (AHL) material if desired, or the option material can be taught as a separate unit.

Science and the international dimension

Science itself is an international endeavour—the exchange of information and ideas across national boundaries has been essential to the progress of science. This exchange is not a new phenomenon but it has accelerated in recent times with the development of information and communication technologies. Indeed, the idea that science is a Western invention is a myth—many of the foundations of modern-day science were laid many centuries before by Arabic, Indian and Chinese civilizations, among others. Teachers are encouraged to emphasize this contribution in their teaching of various topics, perhaps through the use of timeline websites. The scientific method in its widest sense, with its emphasis on peer review, open-mindedness and freedom of thought, transcends politics, religion, gender and nationality. Where appropriate within certain topics, the syllabus details sections in the group 4 guides contain links illustrating the international aspects of science.

On an organizational level, many international bodies now exist to promote science. United Nations bodies such as UNESCO, UNEP and WMO, where science plays a prominent part, are well known, but in addition there are hundreds of international bodies representing every branch of science. The facilities for large-scale research in, for example, particle physics and the Human Genome Project are expensive, and only joint ventures involving funding from many countries allow this to take place. The data from such research is shared by scientists worldwide. Group 4 teachers and students are encouraged to access the extensive websites and databases of these international scientific organizations to enhance their appreciation of the international dimension.

Increasingly there is a recognition that many scientific problems are international in nature and this has led to a global approach to research in many areas. The reports of the Intergovernmental Panel on Climate Change are a prime example of this. On a practical level, the group 4 project (which all science students must undertake) mirrors the work of real scientists by encouraging collaboration between schools across the regions.

The power of scientific knowledge to transform societies is unparalleled. It has the potential to produce great universal benefits, or to reinforce inequalities and cause harm to people and the environment. In line with the IB mission statement, group 4 students need to be aware of the moral responsibility of scientists to ensure that scientific knowledge and data are available to all countries on an equitable basis and that they have the scientific capacity to use this for developing sustainable societies.

Students' attention should be drawn to sections of the syllabus with links to international-mindedness. Examples of issues relating to international-mindedness are given within sub-topics in the syllabus content. Teachers could also use resources found on the Global Engage website (http://globalengage.ibo.org).

Distinction between SL and HL

Group 4 students at standard level (SL) and higher level (HL) undertake a common core syllabus, a common internal assessment (IA) scheme and have some overlapping elements in the option studied. They are presented with a syllabus that encourages the development of certain skills, attributes and attitudes, as described in the "Assessment objectives" section of this guide.

While the skills and activities of group 4 science subjects are common to students at both SL and HL, students at HL are required to study some topics in greater depth, in the additional higher level (AHL) material and in the common options. The distinction between SL and HL is one of breadth and depth.

Prior learning

Past experience shows that students will be able to study a group 4 science subject at SL successfully with no background in, or previous knowledge of, science. Their approach to learning, characterized by the IB learner profile attributes, will be significant here.

However, for most students considering the study of a group 4 subject at HL, while there is no intention to restrict access to group 4 subjects, some previous exposure to formal science education would be necessary. Specific topic details are not specified but students who have undertaken the IB Middle Years Programme (MYP) or studied an equivalent national science qualification or a school-based science course would be well prepared for an HL subject.

Links to the Middle Years Programme

Students who have undertaken the MYP science, design and mathematics courses will be well prepared for group 4 subjects. The alignment between MYP science and Diploma Programme group 4 courses allows for a smooth transition for students between programmes. The concurrent planning of the new group 4 courses and MYP: Next chapter (both launched in 2014) has helped develop a closer alignment.

Scientific inquiry is central to teaching and learning science in the MYP. It enables students to develop a way of thinking and a set of skills and processes that, while allowing them to acquire and use knowledge, equip them with the capabilities to tackle, with confidence, the internal assessment component of group 4 subjects. The vision of MYP sciences is to contribute to the development of students as 21st century learners. A holistic sciences programme allows students to develop and utilize a mixture of cognitive abilities, social skills, personal motivation, conceptual knowledge and problem-solving competencies within an inquiry-based learning environment (Rhoton 2010). Inquiry aims to support students' understanding by providing them with opportunities to independently and collaboratively investigate relevant issues through both research and experimentation. This forms a firm base of scientific understanding with deep conceptual roots for students entering group 4 courses.

In the MYP, teachers make decisions about student achievement using their professional judgment, guided by criteria that are public, precise and known in advance, ensuring that assessment is transparent. The IB describes this approach as "criterion-related"—a philosophy of assessment that is neither "norm-referenced" (where students must be compared to each other and to an expected distribution of achievement) nor "criterion-referenced" (where students must master all strands of specific criteria at lower achievement levels before they can be considered to have achieved the next level). It is important to emphasize that the single most important aim of MYP assessment (consistent with the PYP and DP) is to support curricular goals and encourage appropriate student learning. Assessments are based upon evaluating course aims and objectives and, therefore, effective teaching to the course requirements also ensures effective teaching for formal assessment requirements. Students need to understand what the assessment expectations, standards and practices are and these should all be introduced early and naturally in teaching, as well as in class and homework activities. Experience with criterion-related assessment greatly assists students entering group 4 courses with understanding internal assessment requirements.

MYP science is a concept-driven curriculum, aimed at helping the learner construct meaning through improved critical thinking and the transfer of knowledge. At the top level are *key concepts* which are broad, organizing, powerful ideas that have relevance within the science course but also transcend it, having relevance in other subject groups. These key concepts facilitate both disciplinary and interdisciplinary learning as well as making connections with other subjects. While the key concepts provide breadth, the *related concepts* in MYP science add depth to the programme. The related concept can be considered to be the big idea of the unit which brings focus and depth and leads students towards the conceptual understanding.

Across the MYP, there are 16 key concepts, with the three highlighted below as the focus for MYP science.

The key concepts across the MYP curriculum			
Aesthetics	**Change**	Communication	Communities
Connections	Creativity	Culture	Development
Form	Global interactions	Identity	Logic
Perspective	**Relationships**	**Systems**	Time, place and space

MYP students may in addition undertake an optional onscreen concept-based assessment as further preparation for Diploma Programme science courses.

Science and theory of knowledge

The theory of knowledge (TOK) course (first assessment 2015) engages students in reflection on the nature of knowledge and on how we know what we claim to know. The course identifies eight ways of knowing: reason, emotion, language, sense perception, intuition, imagination, faith and memory. Students explore these means of producing knowledge within the context of various areas of knowledge: the natural sciences, the social sciences, the arts, ethics, history, mathematics, religious knowledge systems and indigenous knowledge systems. The course also requires students to make comparisons between the different areas of knowledge, reflecting on how knowledge is arrived at in the various disciplines, what the disciplines have in common, and the differences between them.

TOK lessons can support students in their study of science, just as the study of science can support students in their TOK course. TOK provides a space for students to engage in stimulating wider discussions about questions such as what it means for a discipline to be a science, or whether there should be ethical constraints on the pursuit of scientific knowledge. It also provides an opportunity for students to reflect on the methodologies of science, and how these compare to the methodologies of other areas of knowledge. It is now widely accepted that there is no one scientific method, in the strict Popperian sense. Instead, the sciences utilize a variety of approaches in order to produce explanations for the behaviour of the natural world. The different scientific disciplines share a common focus on utilizing inductive and deductive reasoning, on the importance of evidence, and so on. Students are encouraged to compare and contrast these methods with the methods found in, for example, the arts or in history.

In this way there are rich opportunities for students to make links between their science and TOK courses. One way in which science teachers can help students to make these links to TOK is by drawing students' attention to knowledge questions which arise from their subject content. Knowledge questions are open-ended questions about knowledge, and include questions such as:

- How do we distinguish science from pseudoscience?
- When performing experiments, what is the relationship between a scientist's expectation and their perception?
- How does scientific knowledge progress?
- What is the role of imagination and intuition in the sciences?
- What are the similarities and differences in methods in the natural sciences and the human sciences?

Examples of relevant knowledge questions are provided throughout this guide within the sub-topics in the syllabus content. Teachers can also find suggestions of interesting knowledge questions for discussion in the "Areas of knowledge" and "Knowledge frameworks" sections of the TOK guide. Students should be encouraged to raise and discuss such knowledge questions in both their science and TOK classes.

Aims

Group 4 aims

Through studying biology, chemistry or physics, students should become aware of how scientists work and communicate with each other. While the scientific method may take on a wide variety of forms, it is the emphasis on a practical approach through experimental work that characterizes these subjects.

The aims enable students, through the overarching theme of the Nature of science, to:

1. appreciate scientific study and creativity within a global context through stimulating and challenging opportunities
2. acquire a body of knowledge, methods and techniques that characterize science and technology
3. apply and use a body of knowledge, methods and techniques that characterize science and technology
4. develop an ability to analyse, evaluate and synthesize scientific information
5. develop a critical awareness of the need for, and the value of, effective collaboration and communication during scientific activities
6. develop experimental and investigative scientific skills including the use of current technologies
7. develop and apply 21st century communication skills in the study of science
8. become critically aware, as global citizens, of the ethical implications of using science and technology
9. develop an appreciation of the possibilities and limitations of science and technology
10. develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge.

Assessment objectives

The assessment objectives for biology, chemistry and physics reflect those parts of the aims that will be formally assessed either internally or externally. These assessments will centre upon the nature of science. It is the intention of these courses that students are able to fufill the following assessment objectives:

1. Demonstrate knowledge and understanding of:
    a. facts, concepts, and terminology
    b. methodologies and techniques
    c. communicating scientific information.
2. Apply:
    a. facts, concepts, and terminology
    b. methodologies and techniques
    c. methods of communicating scientific information.
3. Formulate, analyse and evaluate:
    a. hypotheses, research questions and predictions
    b. methodologies and techniques
    c. primary and secondary data
    d. scientific explanations.
4. Demonstrate the appropriate research, experimental, and personal skills necessary to carry out insightful and ethical investigations.

Syllabus outline

Syllabus component	Recommended teaching hours	
	SL	HL
Core	**95**	
1. Stoichiometric relationships	13.5	
2. Atomic structure	6	
3. Periodicity	6	
4. Chemical bonding and structure	13.5	
5. Energetics/thermochemistry	9	
6. Chemical kinetics	7	
7. Equilibrium	4.5	
8. Acids and bases	6.5	
9. Redox processes	8	
10. Organic chemistry	11	
11. Measurement and data processing	10	
Additional higher level (AHL)		**60**
12. Atomic structure		2
13. The periodic table—the transition metals		4
14. Chemical bonding and structure		7
15. Energetics/thermochemistry		7
16. Chemical kinetics		6
17. Equilibrium		4
18. Acids and bases		10
19. Redox processes		6
20. Organic chemistry		12
21. Measurement and analysis		2
Option	**15**	**25**
A. Materials	15	25
B. Biochemistry	15	25
C. Energy	15	25
D. Medicinal chemistry	15	25

Syllabus component	Recommended teaching hours	
	SL	HL
Practical scheme of work	**40**	**60**
Practical activities	20	40
Individual investigation (internal assessment—IA)	10	10
Group 4 project	10	10
Total teaching hours	**150**	**240**

The recommended teaching time is 240 hours to complete HL courses and 150 hours to complete SL courses as stated in the document *General regulations: Diploma Programme* (2011) (page 4, Article 8.2).

Approaches to the teaching of chemistry

Format of the syllabus

The format of the syllabus section of the group 4 guides is the same for each subject physics, chemistry and biology. This new structure gives prominence and focus to the teaching and learning aspects.

Topics or options

Topics are numbered and options are indicated by a letter. For example, "Topic 6: Chemical kinetics", or "Option D: Medicinal chemistry".

Sub-topics

Sub-topics are numbered as follows, "6.1 Collision theory and rates of reaction". Further information and guidance about possible teaching times are contained in the teacher support materials.

Each sub-topic begins with an essential idea. The essential idea is an enduring interpretation that is considered part of the public understanding of science. This is followed by a section on the "Nature of science". This gives specific examples in context illustrating some aspects of the nature of science. These are linked directly to specific references in the "Nature of Science" section of the guide to support teachers in their understanding of the general theme to be addressed.

Under the overarching Nature of Science theme there are two columns. The first column lists "Understandings", which are the main general ideas to be taught. There follows an "Applications and skills" section that outlines the specific applications and skills to be developed from the understandings. A "Guidance" section gives information about the limits and constraints and the depth of treatment required for teachers and examiners. The contents of the "Nature of Science" section above the two columns and contents of the first column are all legitimate items for assessment. In addition, some assessment of international-mindedness in science, from the content of the second column, will take place as in the previous course.

The second column gives suggestions to teachers about relevant references to international-mindedness. It also gives examples of TOK knowledge questions (see *Theory of knowledge* guide published 2013) that can be used to focus students' thoughts on the preparation of the TOK prescribed essay. The "Links" section may link the sub-topic to other parts of the subject syllabus, to other Diploma Programme subject guides or to real-world applications. Finally, the "Aims" section refers to how specific group 4 aims are being addressed in the sub-topic.

Format of the guide

Topic 1: <Title>

Essential idea: This lists the essential idea for each sub-topic.

1.1 Sub-topic	
Nature of Science: Relates the sub-topic to the overarching theme of Nature of Science.	
Understandings: • This section will provide specifics of the content requirements for each sub-topic. **Applications and skills:** • The content of this section gives details of how students are to apply the understandings. For example, these applications could involve demonstrating mathematical calculations or practical skills. **Guidance:** • This section will provide specifics and give constraints to the requirements for the understandings and applications and skills. • This section will also include links to specific sections in the data booklet.	**International-mindedness:** • Ideas that teachers can easily integrate into the delivery of their lessons. **Theory of knowledge:** • Examples of TOK knowledge questions. **Utilization:** (including syllabus and cross-curricular links) • Links to other topics within the *Chemistry guide*, to a variety of real-world applications and to other Diploma Programme courses. **Aims:** • Links to the group 4 subject aims.

Group 4 experimental skills

I hear and I forget. I see and I remember. I do and I understand.

(Confucius)

Integral to the experience of students in any of the group 4 courses is their experience in the classroom, laboratory, or in the field. Practical activities allow students to interact directly with natural phenomena and secondary data sources. These experiences provide the students with the opportunity to design investigations, collect data, develop manipulative skills, analyse results, collaborate with peers and evaluate and communicate their findings. Experiments can be used to introduce a topic, investigate a phenomenon or allow students to consider and examine questions and curiosities.

By providing students with the opportunity for hands-on experimentation, they are carrying out some of the same processes that scientists undertake. Experimentation allows students to experience the nature of scientific thought and investigation. All scientific theories and laws begin with observations.

It is important that students are involved in an inquiry-based practical programme that allows for the development of scientific inquiry. It is not enough for students just to be able to follow directions and to simply replicate a given experimental procedure; they must be provided with the opportunities for genuine inquiry. Developing scientific inquiry skills will give students the ability to construct an explanation based on reliable evidence and logical reasoning. Once developed, these higher order thinking skills will enable students to be lifelong learners and scientifically literate.

A school's practical scheme of work should allow students to experience the full breadth and depth of the course including the option. This practical scheme of work must also prepare students to undertake the individual investigation that is required for the internal assessment. The development of students' manipulative skills should involve them being able to follow instructions accurately and demonstrate the safe, competent and methodical use of a range of techniques and equipment.

The "Applications and skills" section of the syllabus lists specific lab skills, techniques and experiments that students must experience at some point during their study of their group 4 course. Other recommended lab skills, techniques and experiments are listed in the "Aims" section of the subject-specific syllabus pages. Aim 6 of the group 4 subjects directly relates to the development of experimental and investigative skills.

Mathematical requirements

All Diploma Programme chemistry students should be able to:

- perform the basic arithmetic functions: addition, subtraction, multiplication and division
- carry out calculations involving means, decimals, fractions, percentages, ratios, approximations and reciprocals
- use standard notation (for example, 3.6×10^6)
- use direct and inverse proportion
- solve simple algebraic equations
- plot graphs (with suitable scales and axes) including two variables that show linear and non-linear relationships
- interpret graphs, including the significance of gradients, changes in gradients, intercepts and areas
- interpret data presented in various forms (for example, bar charts, histograms and pie charts).

Data booklet

The data booklet must be viewed as an integral part of the chemistry programme. It should be used throughout the delivery of the course and not just reserved for use during the external assessments. The data booklet contains useful equations, constants, data, structural formulas and tables of information. In the "Syllabus content" section of the subject guide, explicit links provide direct references to information in the data booklet which will allow students to become familiar with its use and contents. It is suggested that the data booklet be used for all in-class study and school-based assessments.

For both SL and HL external assessments, the data booklet cannot be used for paper 1, but candidates are provided with a copy of the periodic table given in section 6 of that booklet. Clean copies of the data booklet must be made available to both SL and HL candidates for papers 2 and 3.

Use of information communication technology

The use of information communication technology (ICT) is encouraged throughout all aspects of the course in relation to both the practical programme and day-to-day classroom activities. Teachers should make use of the ICT pages of the teacher support materials.

Planning your course

The syllabus as provided in the subject guide is not intended to be a teaching order. Instead it provides detail of what must be covered by the end of the course. A school should develop a scheme of work that best works for its students. For example, the scheme of work could be developed to match available resources, to take into account student prior learning and experience, or in conjunction with other local requirements.

HL teachers may choose to teach the core and AHL topics at the same time or teach them in a spiral fashion, by teaching the core topics in year one of the course and revisiting the core topics through the delivery of the AHL topics in year two of the course. The option topic could be taught as a stand-alone topic or could be integrated into the teaching of the core and/or AHL topics.

However the course is planned, adequate time must be provided for examination revision. Time must also be given for students to reflect on their learning experience and their growth as learners.

The IB learner profile

The chemistry course contributes to the development of attributes of the IB learner profile. By following the course, students will have engaged with the attributes of the IB learner profile. For example, the requirements of the internal assessment provide opportunities for students to develop every aspect of the profile. For each attribute of the learner profile, a number of references from the Group 4 courses are given below.

Learner profile attribute	Biology, chemistry and physics
Inquirers	Aims 2 and 6 Practical work and internal assessment
Knowledgeable	Aims 1 and 10, international-mindedness links Practical work and internal assessment
Thinkers	Aims 3 and 4, Theory of knowledge links Practical work and internal assessment
Communicators	Aims 5 and 7, external assessment Practical work and internal assessment
Principled	Aims 8 and 9 Practical work and internal assessment. Ethical behaviour/practice (*Ethical practice* poster, *IB animal experimentation policy*), academic honesty
Open-minded	Aims 8 and 9, International-mindedness links Practical work and internal assessment, the group 4 project
Caring	Aims 8 and 9 Practical work and internal assessment, the group 4 project, ethical behaviour/practice (*Ethical practice* poster, *IB animal experimentation policy*)

Learner profile attribute	Biology, chemistry and physics
Risk-takers	Aims 1 and 6 Practical work and internal assessment, the group 4 project
Balanced	Aims 8 and 10 Practical work and internal assessment, the group 4 project and fieldwork
Reflective	Aims 5 and 9 Practical work and internal assessment, the group 4 project

Syllabus content

	Recommended teaching hours
Core	**95 hours**
Topic 1: Stoichiometric relationships	**13.5**
1.1 Introduction to the particulate nature of matter and chemical change	
1.2 The mole concept	
1.3 Reacting masses and volumes	
Topic 2: Atomic structure	**6**
2.1 The nuclear atom	
2.2 Electron configuration	
Topic 3: Periodicity	**6**
3.1 Periodic table	
3.2 Periodic trends	
Topic 4: Chemical bonding and structure	**13.5**
4.1 Ionic bonding and structure	
4.2 Covalent bonding	
4.3 Covalent structures	
4.4 Intermolecular forces	
4.5 Metallic bonding	
Topic 5: Energetics/thermochemistry	**9**
5.1 Measuring energy changes	
5.2 Hess's Law	
5.3 Bond enthalpies	
Topic 6: Chemical kinetics	**7**
6.1 Collision theory and rates of reaction	
Topic 7: Equilibrium	**4.5**
7.1 Equilibrium	

	Recommended teaching hours
Topic 8: Acids and bases	**6.5**
8.1 Theories of acids and bases	
8.2 Properties of acids and bases	
8.3 The pH scale	
8.4 Strong and weak acids and bases	
8.5 Acid deposition	
Topic 9: Redox processes	**8**
9.1 Oxidation and reduction	
9.2 Electrochemical cells	
Topic 10: Organic chemistry	**11**
10.1 Fundamentals of organic chemistry	
10.2 Functional group chemistry	
Topic 11: Measurement and data processing	**10**
11.1 Uncertainties and errors in measurement and results	
11.2 Graphical techniques	
11.3 Spectroscopic identification of organic compounds	
Additional higher level (AHL)	**60 hours**
Topic 12: Atomic structure	**2**
12.1 Electrons in atoms	
Topic 13: The periodic table—the transition metals	**4**
13.1 First-row d-block elements	
13.2 Coloured complexes	
Topic 14: Chemical bonding and structure	**7**
14.1 Covalent bonding and electron domain and molecular geometries	
14.2 Hybridization	
Topic 15: Energetics/thermochemistry	**7**
15.1 Energy cycles	
15.2 Entropy and spontaneity	

	Recommended teaching hours
Topic 16: Chemical kinetics	**6**
16.1 Rate expression and reaction mechanism	
16.2 Activation energy	
Topic 17: Equilibrium	**4**
17.1 The equilibrium law	
Topic 18: Acids and bases	**10**
18.1 Lewis acids and bases	
18.2 Calculations involving acids and bases	
18.3 pH curves	
Topic 19: Redox processes	**6**
19.1 Electrochemical cells	
Topic 20: Organic chemistry	**12**
20.1 Types of organic reactions	
20.2 Synthetic routes	
20.3 Stereoisomerism	
Topic 21: Measurement and analysis	**2**
21.1 Spectroscopic identification of organic compounds	

Options — 15 hours (SL)/25 hours (HL)

A: Materials

Core topics

A.1 Materials science introduction

A.2 Metals and inductively coupled plasma (ICP) spectroscopy

A.3 Catalysts

A.4 Liquid crystals

A.5 Polymers

A.6 Nanotechnology

A.7 Environmental impact—plastics

Additional higher level topics

A.8 Superconducting metals and X-ray crystallography (HL only)

A.9 Condensation polymers (HL only)

A.10 Environmental impact—heavy metals (HL only)

B: Biochemistry

Core topics

B.1 Introduction to biochemistry

B.2 Proteins and enzymes

B.3 Lipids

B.4 Carbohydrates

B.5 Vitamins

B.6 Biochemistry and the environment

Additional higher level topics

B.7 Proteins and enzymes (HL only)

B.8 Nucleic acids (HL only)

B.9 Biological pigments (HL only)

B.10 Stereochemistry in biomolecules (HL only)

C: Energy

Core topics

C.1 Energy sources

C.2 Fossil fuels

C.3 Nuclear fusion and fission

C.4 Solar energy

C.5 Environmental impact—global warming

Additional higher level topics

C.6 Electrochemistry, rechargeable batteries and fuel cells (HL only)

C.7 Nuclear fusion and nuclear fission (HL only)

C.8 Photovoltaic and dye-sensitized solar cells (HL only)

D: Medicinal chemistry

Core topics

D.1 Pharmaceutical products and drug action

D.2 Aspirin and penicillin

D.3 Opiates

D.4 pH regulation of the stomach

D.5 Anti-viral medications

D.6 Environmental impact of some medications

Additional higher level topics

D.7 Taxol—a chiral auxiliary case study (HL only)

D.8 Nuclear medicine (HL only)

D.9 Drug detection and analysis (HL only)

Core

Topic 1: Stoichiometric relationships

13.5 hours

Essential idea: Physical and chemical properties depend on the ways in which different atoms combine.

1.1 Introduction to the particulate nature of matter and chemical change

Nature of science:

Making quantitative measurements with replicates to ensure reliability—definite and multiple proportions. (3.1)

Understandings:

- Atoms of different elements combine in fixed ratios to form compounds, which have different properties from their component elements.
- Mixtures contain more than one element and/or compound that are not chemically bonded together and so retain their individual properties.
- Mixtures are either homogeneous or heterogeneous.

Applications and skills:

- Deduction of chemical equations when reactants and products are specified.
- Application of the state symbols (s), (l), (g) and (aq) in equations.
- Explanation of observable changes in physical properties and temperature during changes of state.

Guidance:

- Balancing of equations should include a variety of types of reactions.
- Names of the changes of state—melting, freezing, vaporization (evaporation and boiling), condensation, sublimation and deposition—should be covered.

International-mindedness:

- Chemical symbols and equations are international, enabling effective communication amongst scientists without need for translation.
- IUPAC (International Union of Pure and Applied Chemistry) is the world authority in developing standardized nomenclature for both organic and inorganic compounds.

Theory of knowledge:

- Chemical equations are the “language” of chemistry. How does the use of universal languages help and hinder the pursuit of knowledge?
- Lavoisier’s discovery of oxygen, which overturned the phlogiston theory of combustion, is an example of a paradigm shift. How does scientific knowledge progress?

Utilization:

- Refrigeration and how it is related to the changes of state.
- Atom economy.
- Freeze-drying of foods.

1.1 Introduction to the particulate nature of matter and chemical change	
• The term "latent heat" is not required. • Names and symbols of elements are in the data booklet in section 5.	Syllabus and cross-curricular links: Topic 4.1—deduction of formulae of ionic compounds Topic 5.1—enthalpy cycle reaction; standard state of an element or compound Topic 6.1—kinetic theory Topic 8.2—neutralization reactions Topic 10.2—combustion reactions Option A.4—liquid crystals **Aims:** • **Aim 8**: The negative environmental impacts of refrigeration and air conditioning systems are significant. The use of CFCs as refrigerants has been a major contributor to ozone depletion.

Essential idea: The mole makes it possible to correlate the number of particles with the mass that can be measured.

1.2 The mole concept	
Nature of science: Concepts—the concept of the mole developed from the related concept of "equivalent mass" in the early 19th century. (2.3)	
Understandings: • The mole is a fixed number of particles and refers to the amount, *n*, of substance. • Masses of atoms are compared on a scale relative to ^{12}C and are expressed as relative atomic mass (A_r) and relative formula/molecular mass (M_r). • Molar mass (M) has the units g mol^{-1}. • The empirical formula and molecular formula of a compound give the simplest ratio and the actual number of atoms present in a molecule respectively. **Applications and skills:** • Calculation of the molar masses of atoms, ions, molecules and formula units. • Solution of problems involving the relationships between the number of particles, the amount of substance in moles and the mass in grams. • Interconversion of the percentage composition by mass and the empirical formula. • Determination of the molecular formula of a compound from its empirical formula and molar mass. • Obtaining and using experimental data for deriving empirical formulas from reactions involving mass changes.	**International-mindedness:** • The SI system (Système International d'Unités) refers to the metric system of measurement, based on seven base units. • The International Bureau of Weights and Measures (BIPM according to its French initials) is an international standards organization, which aims to ensure uniformity in the application of SI units around the world. **Theory of knowledge:** • The magnitude of Avogadro's constant is beyond the scale of our everyday experience. How does our everyday experience limit our intuition? **Utilization:** • Stoichiometric calculations are fundamental to chemical processes in research and industry, for example in the food, medical, pharmaceutical and manufacturing industries. • The molar volume for crystalline solids is determined by the technique of X-ray crystallography. Syllabus and cross-curricular links: Topic 2.1—the scale of atoms and their component particles Topics 4.1, 4.3 and 4.5—lattice structure of ionic compounds, molecular structure of covalent compounds and metallic lattice Topics 5.1 and 15.2—standard enthalpy and entropy changes defined per mole Topic 19.1—mole ratios of products in electrolysis

1.2 The mole concept	
Guidance: • The value of the Avogadro's constant (*L* or N_A) is given in the data booklet in section 2 and will be given for paper 1 questions. • The generally used unit of molar mass (g mol^{-1}) is a derived SI unit.	**Aims:** • **Aim 6**: Experiments could include percent mass of hydrates, burning of magnesium or calculating Avogadro's number. • **Aim 7**: Data loggers can be used to measure mass changes during reactions.

Essential idea: Mole ratios in chemical equations can be used to calculate reacting ratios by mass and gas volume.

1.3 Reacting masses and volumes	
Nature of science: Making careful observations and obtaining evidence for scientific theories—Avogadro's initial hypothesis. (1.8)	
Understandings: • Reactants can be either limiting or excess. • The experimental yield can be different from the theoretical yield. • Avogadro's law enables the mole ratio of reacting gases to be determined from volumes of the gases. • The molar volume of an ideal gas is a constant at specified temperature and pressure. • The molar concentration of a solution is determined by the amount of solute and the volume of solution. • A standard solution is one of known concentration. **Applications and skills:** • Solution of problems relating to reacting quantities, limiting and excess reactants, theoretical, experimental and percentage yields. • Calculation of reacting volumes of gases using Avogadro's law. • Solution of problems and analysis of graphs involving the relationship between temperature, pressure and volume for a fixed mass of an ideal gas. • Solution of problems relating to the ideal gas equation. • Explanation of the deviation of real gases from ideal behaviour at low	**International-mindedness:** • The SI unit of pressure is the Pascal (Pa), N m^{-2}, but many other units remain in common usage in different countries. These include atmosphere (atm), millimetres of mercury (mm Hg), Torr, bar and pounds per square inch (psi). The bar (10^5 Pa) is now widely used as a convenient unit, as it is very close to 1 atm. The SI unit for volume is m^3, although litre is a commonly used unit. **Theory of knowledge:** • Assigning numbers to the masses of the chemical elements has allowed chemistry to develop into a physical science. Why is mathematics so effective in describing the natural world? • The ideal gas equation can be deduced from a small number of assumptions of ideal behaviour. What is the role of reason, perception, intuition and imagination in the development of scientific models? **Utilization:** • Gas volume changes during chemical reactions are responsible for the inflation of air bags in vehicles and are the basis of many other explosive reactions, such as the decomposition of TNT (trinitrotoluene). • The concept of percentage yield is vital in monitoring the efficiency of industrial processes. Syllabus and cross-curricular links: Topic 4.4—intermolecular forces Topic 5.1—calculations of molar enthalpy changes

1.3 Reacting masses and volumes	
temperature and high pressure. • Obtaining and using experimental values to calculate the molar mass of a gas from the ideal gas equation. • Solution of problems involving molar concentration, amount of solute and volume of solution. • Use of the experimental method of titration to calculate the concentration of a solution by reference to a standard solution. **Guidance:** • Values for the molar volume of an ideal gas are given in the data booklet in section 2. • The ideal gas equation, $PV = nRT$, and the value of the gas constant (*R*) are given in the data booklet in sections 1 and 2. • Units of concentration to include: g dm^{-3}, mol dm^{-3} and parts per million (ppm). • The use of square brackets to denote molar concentration is required.	Topic 9.1—redox titrations Topic 17.1—equilibrium calculations Topic 18.2—acid-base titrations Topic 21.1 and A.8—X-ray crystallography Physics topic 3.2—Ideal gas law **Aims:** • **Aim 6**: Experimental design could include excess and limiting reactants. Experiments could include gravimetric determination by precipitation of an insoluble salt. • **Aim 7**: Data loggers can be used to measure temperature, pressure and volume changes in reactions or to determine the value of the gas constant, *R*. • **Aim 8**: The unit parts per million, ppm, is commonly used in measuring small levels of pollutants in fluids. This unit is convenient for communicating very low concentrations, but is not a formal SI unit.

Topic 2: Atomic structure

6 hours

Essential idea: The mass of an atom is concentrated in its minute, positively charged nucleus.

2.1 The nuclear atom

Nature of science:

Evidence and improvements in instrumentation—alpha particles were used in the development of the nuclear model of the atom that was first proposed by Rutherford. (1.8)

Paradigm shifts—the subatomic particle theory of matter represents a paradigm shift in science that occurred in the late 1800s. (2.3)

Understandings:

- Atoms contain a positively charged dense nucleus composed of protons and neutrons (nucleons).
- Negatively charged electrons occupy the space outside the nucleus.
- The mass spectrometer is used to determine the relative atomic mass of an element from its isotopic composition.

Applications and skills:

- Use of the nuclear symbol notation ${}^{A}_{Z}X$ to deduce the number of protons, neutrons and electrons in atoms and ions.
- Calculations involving non-integer relative atomic masses and abundance of isotopes from given data, including mass spectra.

Guidance:

- Relative masses and charges of the subatomic particles should be known, actual values are given in section 4 of the data booklet. The mass of the electron can be considered negligible.
- Specific examples of isotopes need not be learned.
- The operation of the mass spectrometer is not required.

International-mindedness:

- Isotope enrichment uses physical properties to separate isotopes of uranium, and is employed in many countries as part of nuclear energy and weaponry programmes.

Theory of knowledge:

- Richard Feynman: "If all of scientific knowledge were to be destroyed and only one sentence passed on to the next generation, I believe it is that all things are made of atoms." Are the models and theories which scientists create accurate descriptions of the natural world, or are they primarily useful interpretations for prediction, explanation and control of the natural world?
- No subatomic particles can be (or will be) directly observed. Which ways of knowing do we use to interpret indirect evidence, gained through the use of technology?

Utilization:

- Radioisotopes are used in nuclear medicine for diagnostics, treatment and research, as tracers in biochemical and pharmaceutical research, and as "chemical clocks" in geological and archaeological dating.
- PET (positron emission tomography) scanners give three-dimensional images of tracer concentration in the body, and can be used to detect cancers.

2.1 The nuclear atom	
	Syllabus and cross-curricular links: Topics 11.3, 21.1 and options D.8 and D.9—NMR Options C.3 and C.7—nuclear fission Option D.8—nuclear medicine **Aims:** • **Aim 7**: Simulations of Rutherford's gold foil experiment can be undertaken. • **Aim 8**: Radionuclides carry dangers to health due to their ionizing effects on cells.

Essential idea: The electron configuration of an atom can be deduced from its atomic number.

2.2 Electron configuration

Nature of science:

Developments in scientific research follow improvements in apparatus—the use of electricity and magnetism in Thomson's cathode rays.(1.8)

Theories being superseded—quantum mechanics is among the most current models of the atom. (1.9)

Use theories to explain natural phenomena—line spectra explained by the Bohr model of the atom. (2.2)

Understandings:

- Emission spectra are produced when photons are emitted from atoms as excited electrons return to a lower energy level.
- The line emission spectrum of hydrogen provides evidence for the existence of electrons in discrete energy levels, which converge at higher energies.
- The main energy level or shell is given an integer number, *n*, and can hold a maximum number of electrons, $2n^2$.
- A more detailed model of the atom describes the division of the main energy level into s, p, d and f sub-levels of successively higher energies.
- Sub-levels contain a fixed number of orbitals, regions of space where there is a high probability of finding an electron.
- Each orbital has a defined energy state for a given electronic configuration and chemical environment and can hold two electrons of opposite spin.

Applications and skills:

- Description of the relationship between colour, wavelength, frequency and energy across the electromagnetic spectrum.
- Distinction between a continuous spectrum and a line spectrum.

International-mindedness:

- The European Organization for Nuclear Research (CERN) is run by its European member states (20 states in 2013), with involvements from scientists from many other countries. It operates the world's largest particle physics research centre, including particle accelerators and detectors used to study the fundamental constituents of matter.

Theory of knowledge:

- Heisenberg's Uncertainty Principle states that there is a theoretical limit to the precision with which we can know the momentum and the position of a particle. What are the implications of this for the limits of human knowledge?
- "One aim of the physical sciences has been to give an exact picture of the material world. One achievement ... has been to prove that this aim is unattainable." —Jacob Bronowski. What are the implications of this claim for the aspirations of natural sciences in particular and for knowledge in general?

Utilization:

- Absorption and emission spectra are widely used in astronomy to analyse light from stars.
- Atomic absorption spectroscopy is a very sensitive means of determining the presence and concentration of metallic elements.

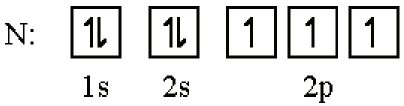
2.2 Electron configuration

- Description of the emission spectrum of the hydrogen atom, including the relationships between the lines and energy transitions to the first, second and third energy levels.
- Recognition of the shape of an s atomic orbital and the p_x, p_y and p_z atomic orbitals.
- Application of the Aufbau principle, Hund's rule and the Pauli exclusion principle to write electron configurations for atoms and ions up to Z = 36.

Guidance:

- Details of the electromagnetic spectrum are given in the data booklet in section 3.
- The names of the different series in the hydrogen line emission spectrum are not required.
- Full electron configurations (eg $1s^2 2s^2 2p^6 3s^2 3p^4$) and condensed electron configurations (eg [Ne] $3s^2 3p^4$) should be covered.

Orbital diagrams should be used to represent the character and relative energy of orbitals. Orbital diagrams refer to arrow-in-box diagrams, such as the one given below.



- The electron configurations of Cr and Cu as exceptions should be covered.

- Fireworks—emission spectra.

Syllabus and cross-curricular links:
Topics 3.1 and 3.2—periodicity
Topic 4.1—deduction of formulae of ionic compounds
Topic 6.1—Maxwell–Boltzmann distribution as a probability density function
Physics topic 7.1 and option D.2—stellar characteristics

Aims:

- **Aim 6**: Emission spectra could be observed using discharge tubes of different gases and a spectroscope. Flame tests could be used to study spectra.

Topic 3: Periodicity

6 hours

Essential idea: The arrangement of elements in the periodic table helps to predict their electron configuration.

3.1 Periodic table

Nature of science:

Obtain evidence for scientific theories by making and testing predictions based on them—scientists organize subjects based on structure and function; the periodic table is a key example of this. Early models of the periodic table from Mendeleev, and later Moseley, allowed for the prediction of properties of elements that had not yet been discovered. (1.9)

Understandings:

- The periodic table is arranged into four blocks associated with the four sub-levels—s, p, d, and f.
- The periodic table consists of groups (vertical columns) and periods (horizontal rows).
- The period number (*n*) is the outer energy level that is occupied by electrons.
- The number of the principal energy level and the number of the valence electrons in an atom can be deduced from its position on the periodic table.
- The periodic table shows the positions of metals, non-metals and metalloids.

Applications and skills:

- Deduction of the electron configuration of an atom from the element's position on the periodic table, and vice versa.

Guidance:

- The terms alkali metals, halogens, noble gases, transition metals, lanthanoids and actinoids should be known.
- The group numbering scheme from group 1 to group 18, as recommended by IUPAC, should be used.

International-mindedness:

- The development of the periodic table took many years and involved scientists from different countries building upon the foundations of each other's work and ideas.

Theory of knowledge:

- What role did inductive and deductive reasoning play in the development of the periodic table? What role does inductive and deductive reasoning have in science in general?

Utilization:

- Other scientific subjects also use the periodic table to understand the structure and reactivity of elements as it applies to their own disciplines.

Syllabus and cross-curricular links:
Topic 2.2—electron configuration

Aims:

- **Aim 3**: Apply the organization of the periodic table to understand general trends in properties.
- **Aim 4**: Be able to analyse data to explain the organization of the elements.
- **Aim 6**: Be able to recognize physical samples or images of common elements.

Essential idea: Elements show trends in their physical and chemical properties across periods and down groups.

3.2 Periodic trends	
Nature of science: Looking for patterns—the position of an element in the periodic table allows scientists to make accurate predictions of its physical and chemical properties. This gives scientists the ability to synthesize new substances based on the expected reactivity of elements. (3.1)	
Understandings: • Vertical and horizontal trends in the periodic table exist for atomic radius, ionic radius, ionization energy, electron affinity and electronegativity. • Trends in metallic and non-metallic behaviour are due to the trends above. • Oxides change from basic through amphoteric to acidic across a period. **Applications and skills:** • Prediction and explanation of the metallic and non-metallic behaviour of an element based on its position in the periodic table. • Discussion of the similarities and differences in the properties of elements in the same group, with reference to alkali metals (group 1) and halogens (group 17). • Construction of equations to explain the pH changes for reactions of Na_2O, MgO, P_4O_{10}, and the oxides of nitrogen and sulfur with water. **Guidance:** • Only examples of general trends across periods and down groups are required. For ionization energy the discontinuities in the increase across a period should be covered. • Group trends should include the treatment of the reactions of alkali metals with water, alkali metals with halogens and halogens with halide ions.	**International-mindedness:** • Industrialization has led to the production of many products that cause global problems when released into the environment. **Theory of knowledge:** • The predictive power of Mendeleev's Periodic Table illustrates the "risk-taking" nature of science. What is the demarcation between scientific and pseudoscientific claims? • The Periodic Table is an excellent example of classification in science. How does classification and categorization help and hinder the pursuit of knowledge? **Utilization:** Syllabus and cross-curricular links: Topic 2.2—anomalies in first ionization energy values can be connected to stability in electron configuration Topic 8.5—production of acid rain **Aims:** • **Aims 1** and **8**: What is the global impact of acid deposition? • **Aim 6**: Experiment with chemical trends directly in the laboratory or through the use of teacher demonstrations. • **Aim 6**: The use of transition metal ions as catalysts could be investigated. • **Aim 7**: Periodic trends can be studied with the use of computer databases.

Topic 4: Chemical bonding and structure

13.5 hours

Essential idea: Ionic compounds consist of ions held together in lattice structures by ionic bonds.

4.1 Ionic bonding and structure

Nature of science:

Use theories to explain natural phenomena—molten ionic compounds conduct electricity but solid ionic compounds do not. The solubility and melting points of ionic compounds can be used to explain observations. (2.2)

Understandings:

- Positive ions (cations) form by metals losing valence electrons.
- Negative ions (anions) form by non-metals gaining electrons.
- The number of electrons lost or gained is determined by the electron configuration of the atom.
- The ionic bond is due to electrostatic attraction between oppositely charged ions.
- Under normal conditions, ionic compounds are usually solids with lattice structures.

Applications and skills:

- Deduction of the formula and name of an ionic compound from its component ions, including polyatomic ions.
- Explanation of the physical properties of ionic compounds (volatility, electrical conductivity and solubility) in terms of their structure.

Guidance:

- Students should be familiar with the names of these polyatomic ions: NH_4^+, OH^-, NO_3^-, HCO_3^-, CO_3^{2-}, SO_4^{2-} and PO_4^{3-}.

Theory of knowledge:

- General rules in chemistry (like the octet rule) often have exceptions. How many exceptions have to exist for a rule to cease to be useful?
- What evidence do you have for the existence of ions? What is the difference between direct and indirect evidence?

Utilization:

- Ionic liquids are efficient solvents and electrolytes used in electric power sources and green industrial processes.

Syllabus and cross-curricular links:
Topic 3.2—periodic trends
Topic 21.1 and Option A.8—use of X-ray crystallography in structural determinations
Physics topic 5.1—electrostatics

Aims:

- **Aim 3**: Use naming conventions to name ionic compounds.
- **Aim 6**: Students could investigate compounds based on their bond type and properties or obtain sodium chloride by solar evaporation.
- **Aim 7**: Computer simulation could be used to observe crystal lattice structures.

Essential idea: Covalent compounds form by the sharing of electrons.

4.2. Covalent bonding	
Nature of science: Looking for trends and discrepancies—compounds containing non-metals have different properties than compounds that contain non-metals and metals. (2.5) Use theories to explain natural phenomena—Lewis introduced a class of compounds which share electrons. Pauling used the idea of electronegativity to explain unequal sharing of electrons. (2.2)	
Understandings: • A covalent bond is formed by the electrostatic attraction between a shared pair of electrons and the positively charged nuclei. • Single, double and triple covalent bonds involve one, two and three shared pairs of electrons respectively. • Bond length decreases and bond strength increases as the number of shared electrons increases. • Bond polarity results from the difference in electronegativities of the bonded atoms. **Applications and skills:** • Deduction of the polar nature of a covalent bond from electronegativity values. **Guidance:** • Bond polarity can be shown either with partial charges, dipoles or vectors. • Electronegativity values are given in the data booklet in section 8.	**Utilization:** • Microwaves—cooking with polar molecules. Syllabus and cross-curricular links: Topic 10.1—organic molecules **Aims:** • **Aim 3**: Use naming conventions to name covalently bonded compounds.

Essential idea: Lewis (electron dot) structures show the electron domains in the valence shell and are used to predict molecular shape.

4.3 Covalent structures

Nature of science:

Scientists use models as representations of the real world—the development of the model of molecular shape (VSEPR) to explain observable properties. (1.10)

Understandings:

- Lewis (electron dot) structures show all the valence electrons in a covalently bonded species.
- The “octet rule” refers to the tendency of atoms to gain a valence shell with a total of 8 electrons.
- Some atoms, like Be and B, might form stable compounds with incomplete octets of electrons.
- Resonance structures occur when there is more than one possible position for a double bond in a molecule.
- Shapes of species are determined by the repulsion of electron pairs according to VSEPR theory.
- Carbon and silicon form giant covalent/network covalent structures.

Applications and skills:

- Deduction of Lewis (electron dot) structure of molecules and ions showing all valence electrons for up to four electron pairs on each atom.
- The use of VSEPR theory to predict the electron domain geometry and the molecular geometry for species with two, three and four electron domains.
- Prediction of bond angles from molecular geometry and presence of non-bonding pairs of electrons.
- Prediction of molecular polarity from bond polarity and molecular geometry.
- Deduction of resonance structures, examples include but are not limited to C_6H_6, CO_3^{2-} and O_3.

Theory of knowledge:

- Does the need for resonance structures decrease the value or validity of Lewis (electron dot) theory? What criteria do we use in assessing the validity of a scientific theory?

Utilization:

Syllabus and cross-curricular links:
Option A.7—biodegradability of plastics
Biology topic 2.3—3-D structure of molecules and relating structure to function

Aims:

- **Aim 7**: Computer simulations could be used to model VSEPR structures.

4.3 Covalent structures	
• Explanation of the properties of giant covalent compounds in terms of their structures. **Guidance:** • The term “electron domain” should be used in place of “negative charge centre”. • Electron pairs in a Lewis (electron dot) structure can be shown as dots, crosses, a dash or any combination. • Allotropes of carbon (diamond, graphite, graphene, C_{60} buckminsterfullerene) and SiO_2 should be covered. • Coordinate covalent bonds should be covered.	

Essential idea: The physical properties of molecular substances result from different types of forces between their molecules.

4.4 Intermolecular forces

Nature of science:

Obtain evidence for scientific theories by making and testing predictions based on them—London (dispersion) forces and hydrogen bonding can be used to explain special interactions. For example, molecular covalent compounds can exist in the liquid and solid states. To explain this, there must be attractive forces between their particles which are significantly greater than those that could be attributed to gravity. (2.2)

Understandings:

- Intermolecular forces include London (dispersion) forces, dipole-dipole forces and hydrogen bonding.
- The relative strengths of these interactions are London (dispersion) forces < dipole-dipole forces < hydrogen bonds.

Applications and skills

- Deduction of the types of intermolecular force present in substances, based on their structure and chemical formula.
- Explanation of the physical properties of covalent compounds (volatility, electrical conductivity and solubility) in terms of their structure and intermolecular forces.

Guidance:

- The term “London (dispersion) forces” refers to instantaneous induced dipole-induced dipole forces that exist between any atoms or groups of atoms and should be used for non-polar entities. The term “van der Waals” is an inclusive term, which includes dipole–dipole, dipole-induced dipole and London (dispersion) forces.

Theory of knowledge:

- The nature of the hydrogen bond is the topic of much discussion and the current definition from the IUPAC gives six criteria which should be used as evidence for the occurrence of hydrogen bonding. How does a specialized vocabulary help and hinder the growth of knowledge?

Utilization:

Syllabus and cross-curricular links:
Option A.5—using plasticizers
Option A.7—controlling biodegradability
Option B.3—melting points of *cis-/trans-* fats
Biology topics 2.2, 2.3, 2.4 and 2.6—understanding of intermolecular forces to work with molecules in the body

Aims:

- **Aim 7**: Computer simulations could be used to show intermolecular forces interactions.

Essential idea: Metallic bonds involve a lattice of cations with delocalized electrons.

4.5 Metallic bonding

Nature of science:

Use theories to explain natural phenomena—the properties of metals are different from covalent and ionic substances and this is due to the formation of non-directional bonds with a "sea" of delocalized electrons. (2.2)

Understandings:

- A metallic bond is the electrostatic attraction between a lattice of positive ions and delocalized electrons.
- The strength of a metallic bond depends on the charge of the ions and the radius of the metal ion.
- Alloys usually contain more than one metal and have enhanced properties.

Applications and skills:

- Explanation of electrical conductivity and malleability in metals.
- Explanation of trends in melting points of metals.
- Explanation of the properties of alloys in terms of non-directional bonding.

Guidance:

- Trends should be limited to s- and p-block elements.
- Examples of various alloys should be covered.

International-mindedness:

- The availability of metal resources, and the means to extract them, varies greatly in different countries, and is a factor in determining national wealth. As technologies develop, the demands for different metals change and careful strategies are needed to manage the supply of these finite resources.

Utilization:

Syllabus and cross-curricular links:
Option A.6—use of metals in nanotechnology
Biology topic 2.2—water

Aims:

- **Aim 1**: Global impact of value of precious metals and their extraction processes and locations.
- **Aim 7**: Computer simulations could be used to view examples of metallic bonding.

Topic 5: Energetics/thermochemistry

9 hours

Essential idea: The enthalpy changes from chemical reactions can be calculated from their effect on the temperature of their surroundings.

5.1 Measuring energy changes

Nature of science:

Fundamental principle—conservation of energy is a fundamental principle of science. (2.6)

Making careful observations—measurable energy transfers between systems and surroundings. (3.1)

Understandings:

- Heat is a form of energy.
- Temperature is a measure of the average kinetic energy of the particles.
- Total energy is conserved in chemical reactions.
- Chemical reactions that involve transfer of heat between the system and the surroundings are described as endothermic or exothermic.
- The enthalpy change (ΔH) for chemical reactions is indicated in kJ mol^{-1}.
- ΔH values are usually expressed under standard conditions, given by $\Delta H°$, including standard states.

Applications and skills:

- Calculation of the heat change when the temperature of a pure substance is changed using $q = mc\Delta T$.
- A calorimetry experiment for an enthalpy of reaction should be covered and the results evaluated.

Guidance:

- Enthalpy changes of combustion (ΔH_c°) and formation (ΔH_f°)should be covered.
- Consider reactions in aqueous solution and combustion reactions.

International-mindedness:

- The SI unit of temperature is the Kelvin (K), but the Celsius scale (°C), which has the same incremental scaling, is commonly used in most countries. The exception is the USA which continues to use the Fahrenheit scale (°F) for all non-scientific communication.

Theory of knowledge:

- What criteria do we use in judging discrepancies between experimental and theoretical values? Which ways of knowing do we use when assessing experimental limitations and theoretical assumptions?

Utilization:

- Determining energy content of important substances in food and fuels.

Syllabus and cross-curricular links:
Topic 1.1—conservation of mass, changes of state
Topic 1.2—the mole concept

Aims:

- **Aim 6**: Experiments could include calculating enthalpy changes from given experimental data (energy content of food, enthalpy of melting of ice or the enthalpy change of simple reactions in aqueous solution).
- **Aim 7**: Use of databases to analyse the energy content of food.
- **Aim 7**: Use of data loggers to record temperature changes.

5.1 Measuring energy changes	
• Standard state refers to the normal, most pure stable state of a substance measured at 100 kPa. Temperature is not a part of the definition of standard state, but 298 K is commonly given as the temperature of interest. • The specific heat capacity of water is provided in the data booklet in section 2. • Students can assume the density and specific heat capacities of aqueous solutions are equal to those of water, but should be aware of this limitation. • Heat losses to the environment and the heat capacity of the calorimeter in experiments should be considered, but the use of a bomb calorimeter is not required.	

Essential idea: In chemical transformations energy can neither be created nor destroyed (the first law of thermodynamics).

5.2 Hess's Law

Nature of science:

Hypotheses—based on the conservation of energy and atomic theory, scientists can test the hypothesis that if the same products are formed from the same initial reactants then the energy change should be the same regardless of the number of steps. (2.4)

Understandings:

- The enthalpy change for a reaction that is carried out in a series of steps is equal to the sum of the enthalpy changes for the individual steps.

Applications and skills:

- Application of Hess's Law to calculate enthalpy changes.
- Calculation of ΔH reactions using ΔH_f° data.
- Determination of the enthalpy change of a reaction that is the sum of multiple reactions with known enthalpy changes.

Guidance:

- Enthalpy of formation data can be found in the data booklet in section 12.
- An application of Hess's Law is
  $\Delta H \text{ reaction} = \Sigma(\Delta H_f^\circ \text{products}) - \Sigma(\Delta H_f^\circ \text{reactants})$.

International-mindedness:

- Recycling of materials is often an effective means of reducing the environmental impact of production, but varies in its efficiency in energy terms in different countries.

Theory of knowledge:

- Hess's Law is an example of the application of the Conservation of Energy. What are the challenges and limitations of applying general principles to specific instances?

Utilization:

- Hess's Law has significance in the study of nutrition, drugs, and Gibbs free energy where direct synthesis from constituent elements is not possible.

Syllabus and cross-curricular links:
Physics topic 2.3—conservation of mass-energy

Aims:

- **Aim 4**: Discuss the source of accepted values and use this idea to critique experiments.
- **Aim 6**: Experiments could include Hess's Law labs.
- **Aim 7**: Use of data loggers to record temperature changes.

Essential idea: Energy is absorbed when bonds are broken and is released when bonds are formed.

<table>
<tr><th colspan="2">5.3 Bond enthalpies</th></tr>
<tr><td colspan="2">Nature of science:
Models and theories—measured energy changes can be explained based on the model of bonds broken and bonds formed. Since these explanations are based on a model, agreement with empirical data depends on the sophistication of the model and data obtained can be used to modify theories where appropriate. (2.2)</td></tr>
<tr><td>Understandings:
• Bond-forming releases energy and bond-breaking requires energy.
• Average bond enthalpy is the energy needed to break one mol of a bond in a gaseous molecule averaged over similar compounds.
Applications and skills:
• Calculation of the enthalpy changes from known bond enthalpy values and comparison of these to experimentally measured values.
• Sketching and evaluation of potential energy profiles in determining whether reactants or products are more stable and if the reaction is exothermic or endothermic.
• Discussion of the bond strength in ozone relative to oxygen in its importance to the atmosphere.
Guidance:
• Bond enthalpy values are given in the data booklet in section 11.
• Average bond enthalpies are only valid for gases and calculations involving bond enthalpies may be inaccurate because they do not take into account intermolecular forces.</td><td>International-mindedness:
• Stratospheric ozone depletion is a particular concern in the polar regions of the planet, although the pollution that causes it comes from a variety of regions and sources. International action and cooperation have helped to ameliorate the ozone depletion problem.
Utilization:
• Energy sources, such as combustion of fossil fuels, require high ΔH values.
Syllabus and cross-curricular links:
Topic 4.3—covalent structures
Aims:
• Aim 6: Experiments could be enthalpy of combustion of propane or butane.
• Aim 7: Data loggers can be used to record temperature changes.
• Aim 8: Moral, ethical, social, economic and environmental consequences of ozone depletion and its causes.</td></tr>
</table>

Topic 6: Chemical kinetics

7 hours

Essential idea: The greater the probability that molecules will collide with sufficient energy and proper orientation, the higher the rate of reaction.

6.1 Collision theory and rates of reaction	
Nature of science: The principle of Occam's razor is used as a guide to developing a theory—although we cannot directly see reactions taking place at the molecular level, we can theorize based on the current atomic models. Collision theory is a good example of this principle. (2.7)	
Understandings: • Species react as a result of collisions of sufficient energy and proper orientation. • The rate of reaction is expressed as the change in concentration of a particular reactant/product per unit time. • Concentration changes in a reaction can be followed indirectly by monitoring changes in mass, volume and colour. • Activation energy (E_a) is the minimum energy that colliding molecules need in order to have successful collisions leading to a reaction. • By decreasing E_a, a catalyst increases the rate of a chemical reaction, without itself being permanently chemically changed. **Applications and skills:** • Description of the kinetic theory in terms of the movement of particles whose average kinetic energy is proportional to temperature in Kelvin. • Analysis of graphical and numerical data from rate experiments.	**International-mindedness:** • Depletion of stratospheric ozone has been caused largely by the catalytic action of CFCs and is a particular concern in the polar regions. These chemicals are released from a variety of regions and sources, so international action and cooperation have been needed to ameliorate the ozone depletion problem. **Theory of knowledge:** • The Kelvin scale of temperature gives a natural measure of the kinetic energy of gas whereas the artificial Celsius scale is based on the properties of water. Are physical properties such as temperature invented or discovered? **Utilization:** Syllabus and cross-curricular links: Topic 5.3—what might be meant by thermodynamically stable vs kinetically stable? Topic 13.1—fireworks and ions Option A.3—everyday uses of catalysts Option B.2—enzymes Biology topic 8.1—metabolism

6.1 Collision theory and rates of reaction	
• Explanation of the effects of temperature, pressure/concentration and particle size on rate of reaction. • Construction of Maxwell–Boltzmann energy distribution curves to account for the probability of successful collisions and factors affecting these, including the effect of a catalyst. • Investigation of rates of reaction experimentally and evaluation of the results. • Sketching and explanation of energy profiles with and without catalysts. **Guidance:** • Calculation of reaction rates from tangents of graphs of concentration, volume or mass vs time should be covered. • Students should be familiar with the interpretation of graphs of changes in concentration, volume or mass against time.	**Aims:** • **Aims 1** and **8**: What are some of the controversies over rate of climate change? Why do these exist? • **Aim 6**: Investigate the rate of a reaction with and without a catalyst. • **Aim 6**: Experiments could include investigating rates by changing concentration of a reactant or temperature. • **Aim 7**: Use simulations to show how molecular collisions are affected by change of macroscopic properties such as temperature, pressure and concentration. • **Aim 8**: The role that catalysts play in the field of green chemistry.

Topic 7: Equilibrium

4.5 hours

Essential idea: Many reactions are reversible. These reactions will reach a state of equilibrium when the rates of the forward and reverse reaction are equal. The position of equilibrium can be controlled by changing the conditions.

7.1 Equilibrium

Nature of science:

Obtaining evidence for scientific theories—isotopic labelling and its use in defining equilibrium. (1.8)

Common language across different disciplines—the term dynamic equilibrium is used in other contexts, but not necessarily with the chemistry definition in mind. (5.5)

Understandings:

- A state of equilibrium is reached in a closed system when the rates of the forward and reverse reactions are equal.
- The equilibrium law describes how the equilibrium constant (K_c) can be determined for a particular chemical reaction.
- The magnitude of the equilibrium constant indicates the extent of a reaction at equilibrium and is temperature dependent.
- The reaction quotient (*Q*) measures the relative amount of products and reactants present during a reaction at a particular point in time. *Q* is the equilibrium expression with non-equilibrium concentrations. The position of the equilibrium changes with changes in concentration, pressure, and temperature.
- A catalyst has no effect on the position of equilibrium or the equilibrium constant.

Applications and skills:

- The characteristics of chemical and physical systems in a state of equilibrium.
- Deduction of the equilibrium constant expression (K_c) from an equation for a homogeneous reaction.
- Determination of the relationship between different equilibrium constants (K_c) for the same reaction at the same temperature.

International-mindedness:

- The Haber process has been described as the most important chemical reaction on Earth as it has revolutionized global food production. However, it also had a large impact on weaponry in both world wars.

Theory of knowledge:

- Scientists investigate the world at different scales; the macroscopic and microscopic. Which ways of knowing allow us to move from the macroscopic to the microscopic?
- Chemistry uses a specialized vocabulary: a closed system is one in which no matter is exchanged with the surroundings. Does our vocabulary simply communicate our knowledge; or does it shape what we can know?
- The career of Fritz Haber coincided with the political upheavals of two world wars. He supervised the release of chlorine on the battlefield in World War I and worked on the production of explosives. How does the social context of scientific work affect the methods and findings of science? Should scientists be held morally responsible for the applications of their discoveries?

Utilization:

- Square brackets are used in chemistry in a range of contexts: eg concentrations (topic 1.3), Lewis (electron dot) structures (topic 4.3) and complexes (topic 14.1).

7.1 Equilibrium	
• Application of Le Châtelier's principle to predict the qualitative effects of changes of temperature, pressure and concentration on the position of equilibrium and on the value of the equilibrium constant. **Guidance:** • Physical and chemical systems should be covered. • Relationship between K_c values for reactions that are multiples or inverses of one another should be covered. • Specific details of any industrial process are not required.	Syllabus and cross-curricular links: Topic 8.4—the behaviour of weak acids and bases **Aims:** • **Aim 6**: Le Châtelier's principle can be investigated qualitatively by looking at pressure, concentration and temperature changes on different equilibrium systems. • **Aim 7**: Animations and simulations can be used to illustrate the concept of dynamic equilibrium. • **Aim 8**: Raise awareness of the moral, ethical, and economic implications of using science and technology. A case study of Fritz Haber can be used to debate the role of scientists in society.

Topic 8: Acids and bases

6.5 hours

Essential idea: Many reactions involve the transfer of a proton from an acid to a base.

8.1 Theories of acids and bases

Nature of science:

Falsification of theories—HCN altering the theory that oxygen was the element which gave a compound its acidic properties allowed for other acid–base theories to develop. (2.5)

Theories being superseded—one early theory of acidity derived from the sensation of a sour taste, but this had been proven false. (1.9)

Public understanding of science—outside of the arena of chemistry, decisions are sometimes referred to as "acid test" or "litmus test". (5.5)

Understandings:

- A Brønsted–Lowry acid is a proton/H^+ donor and a Brønsted–Lowry base is a proton/H^+ acceptor.
- Amphiprotic species can act as both Brønsted–Lowry acids and bases.
- A pair of species differing by a single proton is called a conjugate acid-base pair.

Applications and skills:

- Deduction of the Brønsted–Lowry acid and base in a chemical reaction.
- Deduction of the conjugate acid or conjugate base in a chemical reaction.

Guidance:

- Lewis theory is not required here.
- The location of the proton transferred should be clearly indicated. For example, CH_3COOH/CH_3COO^- rather than $C_2H_4O_2/C_2H_3O_2^-$.
- Students should know the representation of a proton in aqueous solution as both H^+ (aq) and H_3O^+ (aq).
- The difference between the terms amphoteric and amphiprotic should be covered.

International-mindedness:

- *Acidus* means sour in Latin, while *alkali* is derived from the Arabic word for calcined ashes. *Oxygene* means acid-forming in Greek, and reflects the mistaken belief that the element oxygen was responsible for a compound's acidic properties. Acid–base theory has been developed by scientists from around the world, and its vocabulary has been influenced by their languages.

Theory of knowledge:

- Acid and base behaviour can be explained using different theories. How are the explanations in chemistry different from explanations in other subjects such as history?

Utilization:

Syllabus and cross-curricular links:
Topic 3.2—the acid/base character of oxides
Topic 8.5—non-metal oxides are responsible for acid precipitation
Option B.2—amino acids acting as amphiprotic species
Option D.4—antacids are bases which neutralize excess hydrochloric acid in the stomach

Aims:

- **Aim 9**: Each theory has its strengths and limitations. Lavoisier has been called the father of modern chemistry but he was mistaken about oxygen in this context.

Essential idea: The characterization of an acid depends on empirical evidence such as the production of gases in reactions with metals, the colour changes of indicators or the release of heat in reactions with metal oxides and hydroxides.

8.2 Properties of acids and bases	
Nature of science: Obtaining evidence for theories—observable properties of acids and bases have led to the modification of acid–base theories. (1.9)	
Understandings: • Most acids have observable characteristic chemical reactions with reactive metals, metal oxides, metal hydroxides, hydrogen carbonates and carbonates. • Salt and water are produced in exothermic neutralization reactions. **Applications and skills:** • Balancing chemical equations for the reaction of acids. • Identification of the acid and base needed to make different salts. • Candidates should have experience of acid-base titrations with different indicators. **Guidance:** • Bases which are not hydroxides, such as ammonia, soluble carbonates and hydrogen carbonates should be covered. • The colour changes of different indicators are given in the data booklet in section 22.	**Utilization:** • A number of acids and bases are used in our everyday life from rust removers to oven cleaners, from foods to toothpastes, from treatments for bee stings to treatment of wasp stings. Syllabus and cross-curricular links: Topic 1.3—acid–base titrations Topic 3.2—the acid/base character of oxides Topic 5.1—enthalpy change of neutralization reactions **Aims:** • **Aim 6**: The evidence for these properties could be based on a student's experimental experiences.

Essential idea: The pH scale is an artificial scale used to distinguish between acid, neutral and basic/alkaline solutions.

8.3 The pH scale	
Nature of science: Occam's razor—the pH scale is an attempt to scale the relative acidity over a wide range of H^+ concentrations into a very simple number. (2.7)	
Understandings: • $\mathrm{pH} = -\log[\mathrm{H^+(aq)}]$ and $[\mathrm{H^+}] = 10^{-\mathrm{pH}}$. • A change of one pH unit represents a 10-fold change in the hydrogen ion concentration $[H^+]$. • pH values distinguish between acidic, neutral and alkaline solutions. • The ionic product constant, $Kw = [\mathrm{H^+}][\mathrm{OH^-}] = 10^{-14}$ at 298 K. **Applications and skills:** • Solving problems involving pH, $[\mathrm{H^+}]$ and $[\mathrm{OH^-}]$. • Students should be familiar with the use of a pH meter and universal indicator. **Guidance:** • Students will not be assessed on pOH values. • Students should be concerned only with strong acids and bases in this sub-topic. • Knowing the temperature dependence of Kw is not required. • Equations involving H_3O^+ instead of H^+ may be applied.	**Theory of knowledge:** • Chemistry makes use of the universal language of mathematics as a means of communication. Why is it important to have just one "scientific" language? **Utilization:** Syllabus and cross-curricular links: Mathematics SL (topic 1.2) and Mathematics HL (topic 1.2)—study of logs **Aims:** • **Aim 3**: Students should be able to use and apply the pH concept in a range of experimental and theoretical contexts. • **Aim 6**: An acid–base titration could be monitored with an indicator or a pH probe.

Essential idea: The pH depends on the concentration of the solution. The strength of acids or bases depends on the extent to which they dissociate in aqueous solution.

8.4 Strong and weak acids and bases

Nature of science:

Improved instrumentation—the use of advanced analytical techniques has allowed the relative strength of different acids and bases to be quantified. (1.8)

Looking for trends and discrepancies—patterns and anomalies in relative strengths of acids and bases can be explained at the molecular level. (3.1)

The outcomes of experiments or models may be used as further evidence for a claim—data for a particular type of reaction supports the idea that weak acids exist in equilibrium. (1.9)

Understandings:

- Strong and weak acids and bases differ in the extent of ionization.
- Strong acids and bases of equal concentrations have higher conductivities than weak acids and bases.
- A strong acid is a good proton donor and has a weak conjugate base.
- A strong base is a good proton acceptor and has a weak conjugate acid.

Applications and skills:

- Distinction between strong and weak acids and bases in terms of the rates of their reactions with metals, metal oxides, metal hydroxides, metal hydrogen carbonates and metal carbonates and their electrical conductivities for solutions of equal concentrations.

Guidance:

- The terms ionization and dissociation can be used interchangeably.
- See section 21 in the data booklet for a list of weak acids and bases.

Theory of knowledge:

- The strength of an acid can be determined by the use of pH and conductivity probes. In what ways do technologies, which extend our senses, change or reinforce our view of the world?

Utilization:

Syllabus and cross-curricular links:
Topic 1.3—solution chemistry
Topic 7.1—weak acids and basis involve reversible reactions

Aims:

- **Aim 6**: Students should have experimental experience of working qualitatively with both strong and weak acids and bases. Examples to include: H_2SO_4 (aq), HCl (aq), HNO_3 (aq), NaOH (aq), NH_3 (aq).
- **Aim 7**: Students could use data loggers to investigate the strength of acid and bases.

Essential idea: Increased industrialization has led to greater production of nitrogen and sulfur oxides leading to acid rain, which is damaging our environment. These problems can be reduced through collaboration with national and intergovernmental organizations.

8.5 Acid deposition

Nature of science:

Risks and problems—oxides of metals and non-metals can be characterized by their acid–base properties. Acid deposition is a topic that can be discussed from different perspectives. Chemistry allows us to understand and to reduce the environmental impact of human activities. (4.8)

Understandings:

- Rain is naturally acidic because of dissolved CO_2 and has a pH of 5.6. Acid deposition has a pH below 5.6.
- Acid deposition is formed when nitrogen or sulfur oxides dissolve in water to form HNO_3, HNO_2, H_2SO_4 and H_2SO_3.
- Sources of the oxides of sulfur and nitrogen and the effects of acid deposition should be covered.

Applications and skills:

- Balancing the equations that describe the combustion of sulfur and nitrogen to their oxides and the subsequent formation of H_2SO_3, H_2SO_4, HNO_2 and HNO_3.
- Distinction between the pre-combustion and post-combustion methods of reducing sulfur oxides emissions.
- Deduction of acid deposition equations for acid deposition with reactive metals and carbonates.

International-mindedness:

- The polluter country and polluted country are often not the same. Acid deposition is a secondary pollutant that affects regions far from the primary source. Solving this problem requires international cooperation.

Theory of knowledge:

- All rain is acidic but not all rain is “acid rain”. Scientific terms have a precise definition. Does scientific vocabulary simply communicate our knowledge in a neutral way or can it have value-laden terminology?

Utilization:

Syllabus and cross-curricular links:
Topic 3.2—the acid/base character of the oxides
Option B.2—pH change and enzyme activity
Option C.2—sulfur dioxide is produced by the combustion of fossil fuels with high levels of sulfur impurities
Environmental systems and societies topic 5.8—acid deposition
Geography Option G: Urban Environments—urban stress and the sustainable city; HL—Global interactions—environmental change

Aims:

- **Aim 6**: The effects of acid rain on different construction materials could be quantitatively investigated.
- **Aim 8**: A discussion of the impact of acid rain in different countries will help raise awareness of the environmental impact of this secondary pollutant and the political implications.
- **Aim 8**: Other means of reducing oxide production—bus use, car pooling, etc. could be discussed.

Topic 9: Redox processes

8 hours

Essential idea: Redox (reduction–oxidation) reactions play a key role in many chemical and biochemical processes.

9.1 Oxidation and reduction

Nature of science:

How evidence is used—changes in the definition of oxidation and reduction from one involving specific elements (oxygen and hydrogen), to one involving electron transfer, to one invoking oxidation numbers is a good example of the way that scientists broaden similarities to general principles. (1.9)

Understandings:

- Oxidation and reduction can be considered in terms of oxygen gain/hydrogen loss, electron transfer or change in oxidation number.
- An oxidizing agent is reduced and a reducing agent is oxidized.
- Variable oxidation numbers exist for transition metals and for most main-group non-metals.
- The activity series ranks metals according to the ease with which they undergo oxidation.
- The Winkler Method can be used to measure biochemical oxygen demand (BOD), used as a measure of the degree of pollution in a water sample.

Applications and skills:

- Deduction of the oxidation states of an atom in an ion or a compound.
- Deduction of the name of a transition metal compound from a given formula, applying oxidation numbers represented by Roman numerals.
- Identification of the species oxidized and reduced and the oxidizing and reducing agents, in redox reactions.
- Deduction of redox reactions using half-equations in acidic or neutral solutions.
- Deduction of the feasibility of a redox reaction from the activity series or reaction data.

International-mindedness:

- Access to a supply of clean drinking water has been recognized by the United Nations as a fundamental human right, yet it is estimated that over one billion people lack this provision. Disinfection of water supplies commonly uses oxidizing agents such as chlorine or ozone to kill microbial pathogens.

Theory of knowledge:

- Chemistry has developed a systematic language that has resulted in older names becoming obsolete. What has been lost and gained in this process?
- Oxidation states are useful when explaining redox reactions. Are artificial conversions a useful or valid way of clarifying knowledge?

Utilization:

- Aerobic respiration, batteries, solar cells, fuel cells, bleaching by hydrogen peroxide of melanin in hair, household bleach, the browning of food exposed to air, etc.
- Driving under the influence of alcohol is a global problem which results in serious road accidents. A redox reaction is the basis of the breathalyser test.
- Natural and synthetic antioxidants in food chemistry.
- Photochromic lenses.
- Corrosion and galvanization.

9.1 Oxidation and reduction	
• Solution of a range of redox titration problems. • Application of the Winkler Method to calculate BOD. **Guidance:** • Oxidation number and oxidation state are often used interchangeably, though IUPAC does formally distinguish between the two terms. Oxidation numbers are represented by Roman numerals according to IUPAC. • Oxidation states should be represented with the sign given before the number, eg +2 not 2+. • The oxidation state of hydrogen in metal hydrides (-1) and oxygen in peroxides (-1) should be covered. • A simple activity series is given in the data booklet in section 25.	Syllabus and cross-curricular links: Topic 1.3—experimental determination of amounts, masses, volumes and concentrations of solutions Topic 3.2—halogen reactivity Topics 4.1 and 4.2—difference between ionic and covalent bonding Topic 10.2—oxidation of alcohols Biology topics 8.2 and 8.3—redox reactions in physiology **Aims:** • **Aim 6**: Experiments could include demonstrating the activity series, redox titrations and using the Winkler Method to measure BOD. • **Aim 8**: Oxidizing agents such as chlorine can be used as disinfectants. Use of chlorine as a disinfectant is of concern due to its ability to oxidize other species forming harmful by-products (eg trichloromethane).

Essential idea: Voltaic cells convert chemical energy to electrical energy and electrolytic cells convert electrical energy to chemical energy.

9.2 Electrochemical cells	
Nature of science: Ethical implications of research—the desire to produce energy can be driven by social needs or profit. (4.5)	
Understandings: Voltaic (*Galvanic*) cells: • Voltaic cells convert energy from spontaneous, exothermic chemical processes to electrical energy. • Oxidation occurs at the anode (negative electrode) and reduction occurs at the cathode (positive electrode) in a voltaic cell. Electrolytic cells: • Electrolytic cells convert electrical energy to chemical energy, by bringing about non-spontaneous processes. • Oxidation occurs at the anode (positive electrode) and reduction occurs at the cathode (negative electrode) in an electrolytic cell. **Applications and skills:** • Construction and annotation of both types of electrochemical cells. • Explanation of how a redox reaction is used to produce electricity in a voltaic cell and how current is conducted in an electrolytic cell. • Distinction between electron and ion flow in both electrochemical cells. • Performance of laboratory experiments involving a typical voltaic cell using two metal/metal-ion half-cells. • Deduction of the products of the electrolysis of a molten salt.	**International-mindedness:** • Research in space exploration often centres on energy factors. The basic hydrogen–oxygen fuel cell can be used as an energy source in spacecraft, such as those first engineered by NASA in the USA. The International Space Station is a good example of a multinational project involving the international scientific community. **Theory of knowledge:** • Is energy just an abstract concept used to justify why certain types of changes are always associated with each other? Are concepts such as energy **real**? **Utilization:** • Fuel cells. • Heart pacemakers. Syllabus and cross-curricular links: Option C.6—fuel cells Physics topic 5.3—electrochemical cells **Aims:** • **Aim 6**: Construction of a typical voltaic cell using two metal/metal-ion half-cells. • **Aim 6**: Electrolysis experiments could include that of a molten salt. A video could also be used to show some of these electrolytic processes.

9.2 Electrochemical cells	
Guidance: • For voltaic cells, a cell diagram convention should be covered.	• **Aim 8**: Although the hydrogen fuel cell is considered an environmentally friendly, efficient alternative to the internal combustion engine, storage of hydrogen fuel is a major problem. The use of liquid methanol, which can be produced from plants as a carbon neutral fuel (one which does not contribute to the greenhouse effect), in fuel cells has enormous potential. What are the current barriers to the development of fuel cells?

Topic 10: Organic chemistry

11 hours

Essential idea: Organic chemistry focuses on the chemistry of compounds containing carbon.

10.1 Fundamentals of organic chemistry

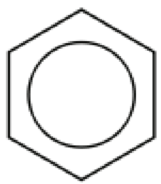
Nature of science:

Serendipity and scientific discoveries—PTFE and superglue. (1.4)

Ethical implications—drugs, additives and pesticides can have harmful effects on both people and the environment. (4.5)

Understandings:

- A homologous series is a series of compounds of the same family, with the same general formula, which differ from each other by a common structural unit.
- Structural formulas can be represented in full and condensed format.
- Structural isomers are compounds with the same molecular formula but different arrangements of atoms.
- Functional groups are the reactive parts of molecules.
- Saturated compounds contain single bonds only and unsaturated compounds contain double or triple bonds.



- Benzene is an aromatic, unsaturated hydrocarbon.

Applications and skills:

- Explanation of the trends in boiling points of members of a homologous series.
- Distinction between empirical, molecular and structural formulas.

International-mindedness:

- A small proportion of nations have control over the world's oil resources. The interdependence of the countries that are net importers and those that are net exporters is an important factor in shaping global policies and economic developments.
- The octane rating (octane number) can be described as a standard measure of the performance of the fuel used in cars and aircraft. Octane ratings often vary quite widely regionally throughout the globe, and are complicated by the fact that different countries use different means of expressing the values.

Theory of knowledge:

- The label "organic chemistry" originates from a misconception that a vital force was needed to explain the chemistry of life. Can you think of examples where vocabulary has developed from similar misunderstandings? Can and should language ever be controlled to eliminate such problems?
- Kekulé claimed that the inspiration for the cyclic structure of benzene came from a dream. What role do the less analytical ways of knowledge play in the acquisition of scientific knowledge?

Utilization:

- Fractional distillation makes great use of many petrochemicals.
- Dyes, pesticides, herbicides, explosives, soap, cosmetics, synthetic scents and flavourings.

10.1 Fundamentals of organic chemistry

- Identification of different classes: alkanes, alkenes, alkynes, halogenoalkanes, alcohols, ethers, aldehydes, ketones, esters, carboxylic acids, amines, amides, nitriles and arenes.
- Identification of typical functional groups in molecules eg phenyl, hydroxyl, carbonyl, carboxyl, carboxamide, aldehyde, ester, ether, amine, nitrile, alkyl, alkenyl and alkynyl.
- Construction of 3-D models (real or virtual) of organic molecules.
- Application of IUPAC rules in the nomenclature of straight-chain and branched-chain isomers.
- Identification of primary, secondary and tertiary carbon atoms in halogenoalkanes and alcohols and primary, secondary and tertiary nitrogen atoms in amines.
- Discussion of the structure of benzene using physical and chemical evidence.

Guidance:

- Skeletal formulas should be discussed in the course.
- The general formulas (eg C_nH_{2n+2}) of alkanes, alkenes, alkynes, ketones, alcohols, aldehydes and carboxylic acids should be known.
- The distinction between class names and functional group names needs to be made. Eg for OH, hydroxyl is the functional group whereas alcohol is the class name.
- The following nomenclature should be covered:
  - non-cyclic alkanes and halogenoalkanes up to halohexanes.
  - alkenes up to hexene and alkynes up to hexyne.
  - compounds up to six carbon atoms (in the basic chain for nomenclature purposes) containing only one of the classes of functional groups: alcohols, ethers, aldehydes, halogenoalkanes, ketones, esters and carboxylic acids.

Syllabus and cross-curricular links:
Topic 1.2—empirical and molecular formulas
Topics 4.2 and 4.3—Lewis (electron dot) structures, multiple bonds, VSEPR theory, resonance and bond and molecular polarity
Topic 4.4—intermolecular forces
Topic 5.3—exothermic reactions and bond enthalpies
Topic 8.4—weak acids
Option A.5—materials and polymers
Options B.2 and B.7—proteins
Option D.9—organic structure in medicines

Aims:

- **Aim 6**: Either use model kits or suitable computer-generated molecular graphics programmes to construct three-dimensional models of a wide range of organic molecules.
- **Aim 6**: Experiments could include distillation to separate liquids or the use of a rotary evaporator to remove a solvent from a mixture.
- **Aim 8**: There are consequences in using fossil fuels as our main source of energy. Many products can be obtained from fossil fuels due to the inherently rich chemistry of carbon. This raises some fundamental questions—are fossil fuels too valuable to burn and how do they affect the environment? Who should be responsible for making decisions in this regard?
- **Aim 8**: Discuss the use of alcohols and biofuels as fuel alternatives to petrol (gasoline) and diesel.

Essential idea: Structure, bonding and chemical reactions involving functional group interconversions are key strands in organic chemistry.

10.2 Functional group chemistry

Nature of science:

Use of data—much of the progress that has been made to date in the developments and applications of scientific research can be mapped back to key organic chemical reactions involving functional group interconversions. (3.1)

Understandings:	International-mindedness:
Alkanes: • Alkanes have low reactivity and undergo free-radical substitution reactions. *Alkenes:* • Alkenes are more reactive than alkanes and undergo addition reactions. Bromine water can be used to distinguish between alkenes and alkanes. *Alcohols:* • Alcohols undergo nucleophilic substitution reactions with acids (also called esterification or condensation) and some undergo oxidation reactions. *Halogenoalkanes:* • Halogenoalkanes are more reactive than alkanes. They can undergo (nucleophilic) substitution reactions. A nucleophile is an electron-rich species containing a lone pair that it donates to an electron-deficient carbon. *Polymers:* • Addition polymers consist of a wide range of monomers and form the basis of the plastics industry. *Benzene:* • Benzene does not readily undergo addition reactions but does undergo electrophilic substitution reactions.	• Methane is a greenhouse gas, and its release from ruminants in countries such as Brazil, Uruguay, Argentina and New Zealand contributes significantly to total greenhouse gas emissions. Landfills are also a source of methane, and technologies are developing in some countries to capture the gas as a source of energy for electricity and heat generation. • Alcohol misuse is a growing problem in many countries and can have an impact on their economies and social structures. **Utilization:** • Alkane usage as fuels. • The role of ethene in fruit ripening. • Alcohols, usage as fuel additives. • Alcohols, role in the breathalyser. • Esters, varied uses—perfumes, food flavourings, solvents, nitroglycerin, biofuels and painkillers. Syllabus and cross-curricular links: Topic 9.1—redox processes Option A.5—polymers Option B.3—lipids

10.2 Functional group chemistry	
Applications and skills: *Alkanes:* • Writing equations for the complete and incomplete combustion of hydrocarbons. • Explanation of the reaction of methane and ethane with halogens in terms of a free-radical substitution mechanism involving photochemical homolytic fission. *Alkenes:* • Writing equations for the reactions of alkenes with hydrogen and halogens and of symmetrical alkenes with hydrogen halides and water. • Outline of the addition polymerization of alkenes. • Relationship between the structure of the monomer to the polymer and repeating unit. *Alcohols:* • Writing equations for the complete combustion of alcohols. • Writing equations for the oxidation reactions of primary and secondary alcohols (using acidified potassium dichromate(VI) or potassium manganate(VII) as oxidizing agents). Explanation of distillation and reflux in the isolation of the aldehyde and carboxylic acid products. • Writing the equation for the condensation reaction of an alcohol with a carboxylic acid, in the presence of a catalyst (eg concentrated sulfuric acid) to form an ester. *Halogenoalkanes:* • Writing the equation for the substitution reactions of halogenoalkanes with aqueous sodium hydroxide.	**Aims:** • **Aim 6**: Experiments could include distinguishing between alkanes and alkenes, preparing soap and the use of gravity filtration, filtration under vacuum (using a Buchner flask), purification including recrystallization, reflux and distillation, melting point determination and extraction. • **Aim 8**: Discuss the significance of the hydrogenation of alkenes in the food production including *trans*-fats as by-products.

10.2 Functional group chemistry	
Guidance: • Reference should be made to initiation, propagation and termination steps in free-radical substitution reactions. Free radicals should be represented by a single dot. • The mechanisms of S_N1 and S_N2 and electrophilic substitution reactions are not required.	

Topic 11: Measurement and data processing

10 hours

Essential idea: All measurement has a limit of precision and accuracy, and this must be taken into account when evaluating experimental results.

11.1 Uncertainties and errors in measurement and results

Nature of science:

Making quantitative measurements with replicates to ensure reliability—precision, accuracy, systematic, and random errors must be interpreted through replication. (3.2, 3.4)

Understandings:

- Qualitative data includes all non-numerical information obtained from observations not from measurement.
- Quantitative data are obtained from measurements, and are always associated with random errors/uncertainties, determined by the apparatus, and by human limitations such as reaction times.
- Propagation of random errors in data processing shows the impact of the uncertainties on the final result.
- Experimental design and procedure usually lead to systematic errors in measurement, which cause a deviation in a particular direction.
- Repeat trials and measurements will reduce random errors but not systematic errors.

Applications and skills:

- Distinction between random errors and systematic errors.
- Record uncertainties in all measurements as a range (±) to an appropriate precision.
- Discussion of ways to reduce uncertainties in an experiment.
- Propagation of uncertainties in processed data, including the use of percentage uncertainties.
- Discussion of systematic errors in all experimental work, their impact on the results and how they can be reduced.
- Estimation of whether a particular source of error is likely to have a major or

International-mindedness:

- As a result of collaboration between seven international organizations, including IUPAC, the International Standards Organization (ISO) published the *Guide to the Expression of Uncertainty in Measurement* in 1995. This has been widely adopted in most countries and has been translated into several languages.

Theory of knowledge:

- Science has been described as a self-correcting and communal public endeavour. To what extent do these characteristics also apply to the other areas of knowledge?

Utilization:

- Crash of the Mars Climate Orbiter spacecraft.
- Original results from CERN regarding the speed of neutrinos were flawed.

Syllabus and cross-curricular links:
Option D.1—drug trials

Aims:

- **Aim 6**: The distinction and different roles of Class A and Class B glassware could be explored.
- **Aim 8**: Consider the moral obligations of scientists to communicate the full extent of their data, including experimental uncertainties. The "cold fusion" case of Fleischmann and Pons in the 1990s is an example of when this was not fulfilled.

11.1 Uncertainties and errors in measurement and results	
minor effect on the final result. • Calculation of percentage error when the experimental result can be compared with a theoretical or accepted result. • Distinction between accuracy and precision in evaluating results. **Guidance:** • The number of significant figures in a result is based on the figures given in the data. When adding or subtracting, the final answer should be given to the least number of decimal places. When multiplying or dividing the final answer is given to the least number of significant figures. • Note that the data value must be recorded to the same precision as the random error. • SI units should be used throughout the programme.	

Essential idea: Graphs are a visual representation of trends in data.

11.2 Graphical techniques	
Nature of science: The idea of correlation—can be tested in experiments whose results can be displayed graphically. (2.8)	
Understandings: • Graphical techniques are an effective means of communicating the effect of an independent variable on a dependent variable, and can lead to determination of physical quantities. • Sketched graphs have labelled but unscaled axes, and are used to show qualitative trends, such as variables that are proportional or inversely proportional. • Drawn graphs have labelled and scaled axes, and are used in quantitative measurements. **Applications and skills:** • Drawing graphs of experimental results including the correct choice of axes and scale. • Interpretation of graphs in terms of the relationships of dependent and independent variables. • Production and interpretation of best-fit lines or curves through data points, including an assessment of when it can and cannot be considered as a linear function. • Calculation of quantities from graphs by measuring slope (gradient) and intercept, including appropriate units.	**International-mindedness:** • Charts and graphs, which largely transcend language barriers, can facilitate communication between scientists worldwide. **Theory of knowledge:** • Graphs are a visual representation of data, and so use sense perception as a way of knowing. To what extent does their interpretation also rely on the other ways of knowing, such as language and reason? **Utilization:** • Graphical representations of data are widely used in diverse areas such as population, finance and climate modelling. Interpretation of these statistical trends can often lead to predictions, and so underpins the setting of government policies in many areas such as health and education. Syllabus and cross-curricular links: Topic 1.3—gas volume, temperature, pressure graphs Topic 6.1—Maxwell–Boltzmann frequency distribution; concentration–time and rate–concentration graphs Topic 16.2—Arrhenius plot to determine activation energy Topic 18.3—titration curves Option B.7—enzyme kinetics Option C.5—greenhouse effect; carbon dioxide concentration and global temperatures Option C.7—first order/decay graph **Aims:** • **Aim 7**: Graph-plotting software may be used, including the use of spreadsheets and the derivation of best-fit lines and gradients.

Essential idea: Analytical techniques can be used to determine the structure of a compound, analyse the composition of a substance or determine the purity of a compound. Spectroscopic techniques are used in the structural identification of organic and inorganic compounds.

11.3 Spectroscopic identification of organic compounds

Nature of science:

Improvements in instrumentation—mass spectrometry, proton nuclear magnetic resonance and infrared spectroscopy have made identification and structural determination of compounds routine. (1.8)

Models are developed to explain certain phenomena that may not be observable—for example, spectra are based on the bond vibration model. (1.10)

Understandings:

- The degree of unsaturation or index of hydrogen deficiency (IHD) can be used to determine from a molecular formula the number of rings or multiple bonds in a molecule.
- Mass spectrometry (MS), proton nuclear magnetic resonance spectroscopy (^{1}H NMR) and infrared spectroscopy (IR) are techniques that can be used to help identify compounds and to determine their structure.

Applications and skills:

- Determination of the IHD from a molecular formula.
- Deduction of information about the structural features of a compound from percentage composition data, MS, ^{1}H NMR or IR.

Guidance:

- The electromagnetic spectrum (EMS) is given in the data booklet in section 3. The regions employed for each technique should be understood.
- The operating principles are not required for any of these methods.

International-mindedness:

- Monitoring and analysis of toxins and xenobiotics in the environment is a continuous endeavour that involves collaboration between scientists in different countries.

Theory of knowledge:

- Electromagnetic waves can transmit information beyond that of our sense perceptions. What are the limitations of sense perception as a way of knowing?

Utilization:

- IR spectroscopy is used in heat sensors and remote sensing in physics.
- Protons in water molecules within human cells can be detected by magnetic resonance imaging (MRI), giving a three-dimensional view of organs in the human body.

Syllabus and cross-curricular links:
Topic 1.2—determination of the empirical formula from percentage composition data or from other experimental data and determination of the molecular formula from both the empirical formula and experimental data.

11.3 Spectroscopic identification of organic compounds	
• The data booklet contains characteristic ranges for IR absorptions (section 26), ^{1}H NMR data (section 27) and specific MS fragments (section 28). For ^{1}H NMR, only the ability to deduce the number of different hydrogen (proton) environments and the relative numbers of hydrogen atoms in each environment is required. Integration traces should be covered but splitting patterns are not required.	Topic 2.1—the nuclear atom Topic 5.3—bond enthalpies **Aims:** • **Aim 7**: Spectral databases could be used here. • **Aim 8**: The effects of the various greenhouse gases depend on their abundance and their ability to absorb heat radiation.

Topic 12: Atomic structure

2 hours

Essential idea: The quantized nature of energy transitions is related to the energy states of electrons in atoms and molecules.

12.1 Electrons in atoms

Nature of science:

Experimental evidence to support theories—emission spectra provide evidence for the existence of energy levels. (1.8)

Understandings:

- In an emission spectrum, the limit of convergence at higher frequency corresponds to the first ionization energy.
- Trends in first ionization energy across periods account for the existence of main energy levels and sub-levels in atoms.
- Successive ionization energy data for an element give information that shows relations to electron configurations.

Applications and skills:

- Solving problems using $E = h\nu$.
- Calculation of the value of the first ionization energy from spectral data which gives the wavelength or frequency of the convergence limit.
- Deduction of the group of an element from its successive ionization energy data.
- Explanation of the trends and discontinuities in first ionization energy across a period.

Guidance:

- The value of Planck's constant (*h*) and $E = h\nu$ are given in the data booklet in sections 1 and 2.
- Use of the Rydberg formula is not expected in calculations of ionization energy.

International-mindedness:

- In 2012 two separate international teams working at the Large Hadron Collider at CERN independently announced that they had discovered a particle with behaviour consistent with the previously predicted "Higgs boson".

Theory of knowledge:

- "What we observe is not nature itself, but nature exposed to our method of questioning."—Werner Heisenberg. An electron can behave as a wave or a particle depending on the experimental conditions. Can sense perception give us objective knowledge about the world?
- The de Broglie equation shows that macroscopic particles have too short a wavelength for their wave properties to be observed. Is it meaningful to talk of properties which can never be observed from sense perception?

Utilization:

- Electron microscopy has led to many advances in biology, such as the ultrastructure of cells and viruses. The scanning tunnelling microscope (STM) uses a stylus of a single atom to scan a surface and provide a 3-D image at the atomic level.

Syllabus and cross-curricular links:
Topic 3.2—periodic trends
Topic 4.1—ionic bonding
Topic 15.1—lattice enthalpy

Aims:

- **Aim 7**: Databases could be used for compiling graphs of trends in ionization energies and simulations are available for the Davisson-Germer electron diffraction experiment.

Topic 13: The periodic table—the transition metals

4 hours

Essential idea: The transition elements have characteristic properties; these properties are related to their all having incomplete d sublevels.

13.1 First-row d-block elements	
Nature of science: Looking for trends and discrepancies—transition elements follow certain patterns of behaviour. The elements Zn, Cr and Cu do not follow these patterns and are therefore considered anomalous in the first-row d-block. (3.1)	
Understandings: • Transition elements have variable oxidation states, form complex ions with ligands, have coloured compounds, and display catalytic and magnetic properties. • Zn is not considered to be a transition element as it does not form ions with incomplete d-orbitals. • Transition elements show an oxidation state of +2 when the s-electrons are removed. **Applications and skills:** • Explanation of the ability of transition metals to form variable oxidation states from successive ionization energies. • Explanation of the nature of the coordinate bond within a complex ion. • Deduction of the total charge given the formula of the ion and ligands present. • Explanation of the magnetic properties in transition metals in terms of unpaired electrons. **Guidance:** • Common oxidation numbers of the transition metal ions are listed in the data booklet in sections 9 and 14.	**International-mindedness:** • The properties and uses of the transition metals make them important international commodities. Mining for precious metals is a major factor in the economies of some countries. **Theory of knowledge:** • The medical symbols for female and male originate from the alchemical symbols for copper and iron. What role has the pseudoscience of alchemy played in the development of modern science? **Utilization:** Syllabus and cross-curricular links: Topic 9.1—redox reactions Topic 10.2—oxidation of alcohols, hydrogenation of alkenes Option A.3—homogeneous and heterogeneous catalysis **Aims:** • **Aim 6**: The oxidation states of vanadium and manganese, for example, could be investigated experimentally. Transition metals could be analysed using redox titrations. • **Aim 8**: Economic impact of the corrosion of iron.

Essential idea: d-orbitals have the same energy in an isolated atom, but split into two sub-levels in a complex ion. The electric field of ligands may cause the d-orbitals in complex ions to split so that the energy of an electron transition between them corresponds to a photon of visible light.

<table>
<tr><th colspan="2">13.2 Coloured complexes</th></tr>
<tr><td colspan="2">Nature of science:
Models and theories—the colour of transition metal complexes can be explained through the use of models and theories based on how electrons are distributed in d-orbitals. (1.10)
Transdisciplinary—colour linked to symmetry can be explored in the sciences, architecture, and the arts. (4.1)</td></tr>
<tr><td>Understandings:
• The d sub-level splits into two sets of orbitals of different energy in a complex ion.
• Complexes of d-block elements are coloured, as light is absorbed when an electron is excited between the d-orbitals.
• The colour absorbed is complementary to the colour observed.
Applications and skills:
• Explanation of the effect of the identity of the metal ion, the oxidation number of the metal and the identity of the ligand on the colour of transition metal ion complexes.
• Explanation of the effect of different ligands on the splitting of the d-orbitals in transition metal complexes and colour observed using the spectrochemical series.
Guidance:
• The spectrochemical series is given in the data booklet in section 15. A list of polydentate ligands is given in the data booklet in section 16.
• Students are not expected to recall the colour of specific complex ions.</td><td>Utilization:
Syllabus and cross-curricular links:
Topic 2.2—electron configuration of atoms and ions
Aims:
• Aim 6: The colours of a range of complex ions, of elements such as Cr, Fe, Co, Ni and Cu could be investigated.
• Aim 7: Complex ions could be investigated using a spectrometer data logger.
• Aim 8: The concentration of toxic transition metal ions needs to be carefully monitored in environmental systems.</td></tr>
</table>

13.2 Coloured complexes	
• The relation between the colour observed and absorbed is illustrated by the colour wheel in the data booklet in section 17. • Students are not expected to know the different splitting patterns and their relation to the coordination number. Only the splitting of the 3-d orbitals in an octahedral crystal field is required.	

Topic 14: Chemical bonding and structure

7 hours

Essential idea: Larger structures and more in-depth explanations of bonding systems often require more sophisticated concepts and theories of bonding.

14.1 Further aspects of covalent bonding and structure

Nature of science:

Principle of Occam's razor—bonding theories have been modified over time. Newer theories need to remain as simple as possible while maximizing explanatory power, for example the idea of formal charge. (2.7)

Understandings:

- Covalent bonds result from the overlap of atomic orbitals. A sigma bond (σ) is formed by the direct head-on/end-to-end overlap of atomic orbitals, resulting in electron density concentrated between the nuclei of the bonding atoms. A pi bond (π) is formed by the sideways overlap of atomic orbitals, resulting in electron density above and below the plane of the nuclei of the bonding atoms.
- Formal charge (FC) can be used to decide which Lewis (electron dot) structure is preferred from several. The FC is the charge an atom would have if all atoms in the molecule had the same electronegativity. FC = (Number of valence electrons)-½(Number of bonding electrons)-(Number of non-bonding electrons). The Lewis (electron dot) structure with the atoms having FC values closest to zero is preferred.
- Exceptions to the octet rule include some species having incomplete octets and expanded octets.
- Delocalization involves electrons that are shared by/between all atoms in a molecule or ion as opposed to being localized between a pair of atoms.
- Resonance involves using two or more Lewis (electron dot) structures to represent a particular molecule or ion. A resonance structure is one of two or more alternative Lewis (electron dot) structures for a molecule or ion that cannot be described fully with one Lewis (electron dot) structure alone.

International-mindedness:

- How has ozone depletion changed over time? What have we done as a global community to reduce ozone depletion?
- To what extent is ozone depletion an example of both a success and a failure for solving an international environmental concern?

Theory of knowledge:

- Covalent bonding can be described using valence bond or molecular orbital theory. To what extent is having alternative ways of describing the same phenomena a strength or a weakness?

Utilization:

- Drug action and links to a molecule's structure.
- Vision science and links to a molecule's structure.

Syllabus and cross-curricular links:
Topics 4.2 and 4.3—Lewis (electron dot) structures, VSEPR theory, resonance and bond and molecular polarity
Topic 10.1—shapes of organic molecules
Topic 13.1—transition metal chemistry

14.1 Further aspects of covalent bonding and structure

Applications and skills:

- Prediction whether sigma (σ) or pi (π) bonds are formed from the linear combination of atomic orbitals.
- Deduction of the Lewis (electron dot) structures of molecules and ions showing all valence electrons for up to six electron pairs on each atom.
- Application of FC to ascertain which Lewis (electron dot) structure is preferred from different Lewis (electron dot) structures.
- Deduction using VSEPR theory of the electron domain geometry and molecular geometry with five and six electron domains and associated bond angles.
- Explanation of the wavelength of light required to dissociate oxygen and ozone.
- Description of the mechanism of the catalysis of ozone depletion when catalysed by CFCs and NO_x.

Guidance:

- The linear combination of atomic orbitals to form molecular orbitals should be covered in the context of the formation of sigma (σ) and pi (π) bonds.
- Molecular polarities of geometries corresponding to five and six electron domains should also be covered.

Aims:

- **Aim 1**: Global impact of ozone depletion.
- **Aim 7**: Computer simulations can be used to model structures predicted by VSEPR theory.
- **Aim 8**: Moral, ethical, social, economic and environmental implications of ozone depletion and its solution.

Essential idea: Hybridization results from the mixing of atomic orbitals to form the same number of new equivalent hybrid orbitals that can have the same mean energy as the contributing atomic orbitals.

14.2 Hybridization

Nature of science:

The need to regard theories as uncertain—hybridization in valence bond theory can help explain molecular geometries, but is limited. Quantum mechanics involves several theories explaining the same phenomena, depending on specific requirements. (2.2)

Understandings:

- A hybrid orbital results from the mixing of different types of atomic orbitals on the same atom.

Applications:

- Explanation of the formation of sp^3, sp^2 and sp hybrid orbitals in methane, ethene and ethyne.
- Identification and explanation of the relationships between Lewis (electron dot) structures, electron domains, molecular geometries and types of hybridization.

Guidance:

- Students need only consider species with sp^3, sp^2 and sp hybridization.

Theory of knowledge:

- Hybridization is a mathematical device which allows us to relate the bonding in a molecule to its symmetry. What is the relationship between the natural sciences, mathematics and the natural world? Which role does symmetry play in the different areas of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 4.3—Lewis (electron dot) structures, VSEPR theory, resonance and bond and molecular polarity
Topic 10.1—shapes of organic molecules
Topic 13.1—transition metal chemistry

Aims:

- **Aim 7**: Computer simulations could be used to model hybrid orbitals.

Topic 15: Energetics/thermochemistry

7 hours

Essential idea: The concept of the energy change in a single step reaction being equivalent to the summation of smaller steps can be applied to changes involving ionic compounds.

15.1 Energy cycles

Nature of science:

Making quantitative measurements with replicates to ensure reliability—energy cycles allow for the calculation of values that cannot be determined directly. (3.2)

Understandings:

- Representative equations (eg $M^+(g) \rightarrow M^+(aq)$) can be used for enthalpy/energy of hydration, ionization, atomization, electron affinity, lattice, covalent bond and solution.
- Enthalpy of solution, hydration enthalpy and lattice enthalpy are related in an energy cycle.

Applications and skills:

- Construction of Born-Haber cycles for group 1 and 2 oxides and chlorides.
- Construction of energy cycles from hydration, lattice and solution enthalpy. For example dissolution of solid NaOH or NH_4Cl in water.
- Calculation of enthalpy changes from Born-Haber or dissolution energy cycles.
- Relate size and charge of ions to lattice and hydration enthalpies.
- Perform lab experiments which could include single replacement reactions in aqueous solutions.

Guidance:

- Polarizing effect of some ions producing covalent character in some largely ionic substances will not be assessed.
- The following enthalpy/energy terms should be covered: ionization, atomization, electron affinity, lattice, covalent bond, hydration and solution.
- Value for lattice enthalpies (section 18), enthalpies of aqueous solutions (section 19) and enthalpies of hydration (section 20) are given in the data booklet.

International-mindedness:

- The importance of being able to obtain measurements of something which cannot be measured directly is significant everywhere. Borehole temperatures, snow cover depth, glacier recession, rates of evaporation and precipitation cycles are among some indirect indicators of global warming. Why is it important for countries to collaborate to combat global problems like global warming?

Utilization:

- Other energy cycles—carbon cycle, the Krebs cycle and electron transfer in biology.

Syllabus and cross-curricular links:
Topics 1.2 and 1.3—stoichiometric relationships
Topic 3.2—ionization energy, atomic and ionic radii
Topic 5.3—bond enthalpy

Aims:

- **Aim 4**: Discuss the source of accepted values and use this idea to critique experiments.
- **Aim 6**: A possible experiment is to calculate either the enthalpy of crystallization of water or the heat capacity of water when a cube of ice is added to hot water.
- **Aim 7**: Use of data loggers to record temperature changes. Use of databases to source accepted values.

Essential idea: A reaction is spontaneous if the overall transformation leads to an increase in total entropy (system plus surroundings). The direction of spontaneous change always increases the total entropy of the universe at the expense of energy available to do useful work. This is known as the second law of thermodynamics.

15.2 Entropy and spontaneity

Nature of science:

Theories can be superseded—the idea of entropy has evolved through the years as a result of developments in statistics and probability. (2.2)

Understandings:

- Entropy (S) refers to the distribution of available energy among the particles. The more ways the energy can be distributed the higher the entropy.
- Gibbs free energy (G) relates the energy that can be obtained from a chemical reaction to the change in enthalpy (ΔH), change in entropy (ΔS), and absolute temperature (T).
- Entropy of gas>liquid>solid under same conditions.

Applications and skills:

- Prediction of whether a change will result in an increase or decrease in entropy by considering the states of the reactants and products.
- Calculation of entropy changes (ΔS) from given standard entropy values (S°).
- Application of $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ in predicting spontaneity and calculation of various conditions of enthalpy and temperature that will affect this.
- Relation of ΔG to position of equilibrium.

Guidance:

- Examine various reaction conditions that affect ΔG.
- ΔG is a convenient way to take into account both the direct entropy change resulting from the transformation of the chemicals, and the indirect entropy change of the surroundings as a result of the gain/loss of heat energy.
- Thermodynamic data is given in section 12 of the data booklet.

International-mindedness:

- Sustainable energy is a UN initiative with a goal of doubling of global sustainable energy resources by 2030.

Theory of knowledge:

- Entropy is a technical term which has a precise meaning. How important are such technical terms in different areas of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 5.2—Hess's Law
Topic 5.3—bond enthalpy
Topic 7.1—equilibrium
Option C.1—quality of energy
Physics option B.2—thermodynamics

Aims:

- **Aims 1**, **4** and **7**: Use of databases to research hypothetical reactions capable of generating free energy.
- **Aim 6**: Experiments investigating endothermic and exothermic processes could be run numerous times to compare reliability of repetitive data and compare to theoretical values.

Topic 16: Chemical kinetics

6 hours

Essential idea: Rate expressions can only be determined empirically and these limit possible reaction mechanisms. In particular cases, such as a linear chain of elementary reactions, no equilibria and only one significant activation barrier, the rate equation is equivalent to the slowest step of the reaction.

16.1 Rate expression and reaction mechanism	
Nature of science: Principle of Occam's razor—newer theories need to remain as simple as possible while maximizing explanatory power. The low probability of three molecule collisions means stepwise reaction mechanisms are more likely. (2.7)	
Understandings: • Reactions may occur by more than one step and the slowest step determines the rate of reaction (rate determining step/RDS). • The molecularity of an elementary step is the number of reactant particles taking part in that step. • The order of a reaction can be either integer or fractional in nature. The order of a reaction can describe, with respect to a reactant, the number of particles taking part in the rate-determining step. • Rate equations can only be determined experimentally. • The value of the rate constant (k) is affected by temperature and its units are determined from the overall order of the reaction. • Catalysts alter a reaction mechanism, introducing a step with lower activation energy. **Applications and skills:** • Deduction of the rate expression for an equation from experimental data and solving problems involving the rate expression. • Sketching, identifying, and analysing graphical representations for zero, first and second order reactions. • Evaluation of proposed reaction mechanisms to be consistent with kinetic and stoichiometric data.	**International-mindedness:** • The first catalyst used in industry was for the production of sulfuric acid. Sulfuric acid production closely mirrored a country's economic health for a long time. What are some current indicators of a country's economic health? **Theory of knowledge:** • Reaction mechanism can be supported by indirect evidence. What is the role of empirical evidence in scientific theories? Can we ever be certain in science? **Utilization:** • Cancer research is all about identifying mechanisms; for carcinogens as well as cancer-killing agents and inhibitors. Syllabus and cross-curricular links: Topic 20.1—organic mechanisms especially S_N1 and S_N2 Option A.3—catalysts Biology topic 8.1—enzymes acting as catalysts **Aims:** • **Aim 7**: Databases, data loggers and other ICT applications can be used to research proposed mechanisms for lab work performed and to carry out virtual experiments to investigate factors which influence rate equations.

16.1 Rate expression and reaction mechanism

Guidance:

- Calculations will be limited to orders with whole number values.
- Consider concentration–time and rate–concentration graphs.
- Use potential energy level profiles to illustrate multi-step reactions; showing the higher E_a in the rate-determining step in the profile.
- Catalysts are involved in the rate-determining step.
- Reactions where the rate-determining step is not the first step should be considered.
- Any experiment which allows students to vary concentrations to see the effect upon the rate and hence determine a rate equation is appropriate.

Essential idea: The activation energy of a reaction can be determined from the effect of temperature on reaction rate.

16.2 Activation energy

Nature of science:

Theories can be supported or falsified and replaced by new theories—changing the temperature of a reaction has a much greater effect on the rate of reaction than can be explained by its effect on collision rates. This resulted in the development of the Arrhenius equation which proposes a quantitative model to explain the effect of temperature change on reaction rate. (2.5)

Understandings:

- The Arrhenius equation uses the temperature dependence of the rate constant to determine the activation energy.
- A graph of *1/T* against ln *k* is a linear plot with gradient – E_a / R and intercept, ln*A*.
- The frequency factor (or pre-exponential factor) (*A*) takes into account the frequency of collisions with proper orientations.

Applications and skills:

- Analysing graphical representation of the Arrhenius equation in its linear form $\ln k = \frac{-E_a}{RT} + \ln A$.
- Using the Arrhenius equation $k = A\,e^{\frac{-E_a}{RT}}$.
- Describing the relationships between temperature and rate constant; frequency factor and complexity of molecules colliding.
- Determining and evaluating values of activation energy and frequency factors from data.

Guidance:

- Use energy level diagrams to illustrate multi-step reactions showing the RDS in the diagram.
- Consider various data sources in using the linear expression $\ln k = \frac{-E_a}{RT} + \ln A$. The expression $\ln\frac{k_1}{k_2} = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ is given in the data booklet.

Utilization:

- The flashing light of fireflies is produced by a chemical process involving enzymes.
- The relationship between the “lock and key” hypothesis of enzymes and the Arrhenius equation.

Syllabus and cross-curricular links:
Topic 6.1—collision theory

Aims:

- **Aims 4** and **7**: Use of simulations and virtual experiments to study effect of temperature and steric factors on rates of reaction.
- **Aim 6**: Experiments could include those involving the collection of temperature readings to obtain sufficient data for a graph.
- **Aim 7**: Graphing calculators can be employed to easily input and analyse data for E_a and frequency factor values.

Topic 17: Equilibrium

4 hours

Essential idea: The position of equilibrium can be quantified by the equilibrium law. The equilibrium constant for a particular reaction only depends on the temperature.

17.1 The equilibrium law

Nature of science:

Employing quantitative reasoning—experimentally determined rate expressions for forward and backward reactions can be deduced directly from the stoichiometric equations and allow Le Châtelier's principle to be applied. (1.8, 1.9)

Understandings:

- Le Châtelier's principle for changes in concentration can be explained by the equilibrium law.
- The position of equilibrium corresponds to a maximum value of entropy and a minimum in the value of the Gibbs free energy.
- The Gibbs free energy change of a reaction and the equilibrium constant can both be used to measure the position of an equilibrium reaction and are related by the equation, $\Delta G = -RT \ln K$.

Applications and skills:

- Solution of homogeneous equilibrium problems using the expression for K_c.
- Relationship between ΔG and the equilibrium constant.
- Calculations using the equation $\Delta G = -RT \ln K$.

Guidance:

- The expression $\Delta G = -RT \ln K$ is given in the data booklet in section 1.
- Students will not be expected to derive the expression $\Delta G = -RT \ln K$.
- The use of quadratic equations will not be assessed.

Theory of knowledge:

- The equilibrium law can be deduced by assuming that the order of the forward and backward reaction matches the coefficients in the chemical equation. What is the role of deductive reasoning in science?
- We can use mathematics successfully to model equilibrium systems. Is this because we create mathematics to mirror reality or because the reality is intrinsically mathematical?
- Many problems in science can only be solved when assumptions are made which simplify the mathematics. What is the role of intuition in problem solving?

Utilization:

- The concept of a closed system in dynamic equilibrium can be applied to a range of systems in the biological, environmental and human sciences.

Syllabus and cross-curricular links:
Topic 1.3—stoichiometric equations
Topic 7.1—equilibrium
Topic 18.2—weak acid and base equilibria
Option A.10—K_{sp}
Options B.7 and D.4—buffer calculations

17.1 The equilibrium law	
	Aims: • **Aim 6**: The equilibrium constant for an esterification reaction and other reactions could be experimentally investigated. • **Aim 7**: The concept of a dynamic equilibrium can be illustrated with computer animations.

Topic 18: Acids and bases

10 hours

Essential idea: The acid–base concept can be extended to reactions that do not involve proton transfer.

18.1 Lewis acids and bases	
Nature of science: Theories can be supported, falsified or replaced by new theories—acid–base theories can be extended to a wider field of applications by considering lone pairs of electrons. Lewis theory doesn't falsify Brønsted–Lowry but extends it. (2.5)	
Understandings: • A Lewis acid is a lone pair acceptor and a Lewis base is a lone pair donor. • When a Lewis base reacts with a Lewis acid a coordinate bond is formed. • A nucleophile is a Lewis base and an electrophile is a Lewis acid. **Applications and skills:** • Application of Lewis' acid–base theory to inorganic and organic chemistry to identify the role of the reacting species. **Guidance:** • Both organic and inorganic examples should be studied. • Relations between Brønsted–Lowry and Lewis acids and bases should be discussed.	**International-mindedness:** • Acid–base theory has developed from the ideas of people from different parts of the world through both collaboration and competition. **Theory of knowledge:** • The same phenomenon can sometimes be explored from different perspectives, and explained by different theories. For example, do we judge competing theories by their universality, simplicity or elegance? **Utilization:** Syllabus and cross-curricular links: Topics 4.2 and 4.3—covalent molecules and Lewis dot diagrams Topic 13.2—transition metal complexes Topic 20.1—nucleophiles **Aims:** • **Aim 6**: Transition metal complexes could be experimentally explored. • **Aim 7**: Animations can be used to distinguish between the different acid–base theories.

Essential idea: The equilibrium law can be applied to acid–base reactions. Numerical problems can be simplified by making assumptions about the relative concentrations of the species involved. The use of logarithms is also significant here.

18.2 Calculations involving acids and bases

Nature of science:

Obtaining evidence for scientific theories—application of the equilibrium law allows strengths of acids and bases to be determined and related to their molecular structure. (1.9)

Understandings:

- The expression for the dissociation constant of a weak acid (K_a) and a weak base (K_b).
- For a conjugate acid base pair, $K_a \times K_b = K_w$.
- The relationship between K_a and pK_a is (pK_a = -log K_a), and between K_b and pK_b is (pK_b = -log K_b).

Applications and skills:

- Solution of problems involving [H^+ (aq)], [OH^-(aq)], pH, pOH, K_a, pK_a, K_b and pK_b.
- Discussion of the relative strengths of acids and bases using values of K_a, pK_a, K_b and pK_b.

Guidance:

- The value K_w depends on the temperature.
- The calculation of pH in buffer solutions will only be assessed in options B.7 and D.4.
- Only examples involving the transfer of one proton will be assessed.
- Calculations of pH at temperatures other than 298 K can be assessed.
- Students should state when approximations are used in equilibrium calculations.
- The use of quadratic equations will not be assessed.

International-mindedness:

- Mathematics is a universal language. The mathematical nature of this topic helps chemists speaking different native languages to communicate more objectively.

Utilization:

Syllabus and cross-curricular links:
Topic 8.1—conjugate acid–base pairs
Topic 8.3—the pH concept
Topic 8.4—strong and weak acids and bases
Options B.7 and D.4—buffers

Aims:

- **Aim 6**: The properties of strong and weak acids could be investigated experimentally.

Essential idea: pH curves can be investigated experimentally but are mathematically determined by the dissociation constants of the acid and base. An indicator with an appropriate end point can be used to determine the equivalence point of the reaction.

18.3 pH curves

Nature of science:

Increased power of instrumentation and advances in available techniques—development in pH meter technology has allowed for more reliable and ready measurement of pH. (3.7)

Understandings:

- The characteristics of the pH curves produced by the different combinations of strong and weak acids and bases.
- An acid–base indicator is a weak acid or a weak base where the components of the conjugate acid–base pair have different colours.
- The relationship between the pH range of an acid–base indicator, which is a weak acid, and its pK_a value.
- The buffer region on the pH curve represents the region where small additions of acid or base result in little or no change in pH.
- The composition and action of a buffer solution.

Applications and skills:

- The general shapes of graphs of pH against volume for titrations involving strong and weak acids and bases with an explanation of their important features.
- Selection of an appropriate indicator for a titration, given the equivalence point of the titration and the end point of the indicator.
- While the nature of the acid–base buffer always remains the same, buffer solutions can be prepared by either mixing a weak acid/base with a solution of a salt containing its conjugate, or by partial neutralization of a weak acid/base with a strong acid/base.
- Prediction of the relative pH of aqueous salt solutions formed by the different combinations of strong and weak acid and base.

Theory of knowledge:

- Is a pH curve an accurate description of reality or an artificial representation? Does science offer a representation of reality?

Utilization:

Syllabus and cross-curricular links:

Topic 5.1—thermometric/conductiometric titrations

Topic 16.2—What are the unusual mathematical features of a pH curve? Students should also be familiar with the use of natural logs when using the Arrhenius expression in topic 16.2

Aims:

- **Aim 6**: Experiments could include investigation of pH curves, determination of the pK_a of a weak acid, preparation and investigation of a buffer solution and the determination of the pK_a of an indicator.
- **Aim 7**: Data logging, databases, spreadsheets and simulations can all be used. For example, the equivalence point could be determined by using a conductivity probe or a temperature probe.

18.3 pH curves	
Guidance: • Only examples involving the transfer of one proton will be assessed. Important features are: – intercept with pH axis – equivalence point – buffer region – points where pK_a = pH or pK_b = pOH. • For an indicator which is a weak acid: – $HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$ Colour A Colour B – The colour change can be considered to take place over a range of $pK_a \pm 1$. • For an indicator which is a weak base: – $BOH(aq) \rightleftharpoons B^+(aq) + OH^-(aq)$ Colour A Colour B • Examples of indicators are listed in the data booklet in section 22. • Salts formed from the four possible combinations of strong and weak acids and bases should be considered. Calculations are not required. • The acidity of hydrated transition metal ions is covered in topic 13. The treatment of other hydrated metal ions is not required.	

Topic 19: Redox processes

6 hours

Essential idea: Energy conversions between electrical and chemical energy lie at the core of electrochemical cells.

19.1 Electrochemical cells

Nature of science:

Employing quantitative reasoning—electrode potentials and the standard hydrogen electrode. (3.1)

Collaboration and ethical implications—scientists have collaborated to work on electrochemical cell technologies and have to consider the environmental and ethical implications of using fuel cells and microbial fuel cells. (4.5)

Understandings:

- A voltaic cell generates an electromotive force (EMF) resulting in the movement of electrons from the anode (negative electrode) to the cathode (positive electrode) via the external circuit. The EMF is termed the cell potential (E°).
- The standard hydrogen electrode (SHE) consists of an inert platinum electrode in contact with 1 mol dm^{-3} hydrogen ion and hydrogen gas at 100 kPa and 298 K. The standard electrode potential (E°) is the potential (voltage) of the reduction half-equation under standard conditions measured relative to the SHE. Solute concentration is 1 mol dm^{-3} or 100 kPa for gases. E° of the SHE is 0 V.
- When aqueous solutions are electrolysed, water can be oxidized to oxygen at the anode and reduced to hydrogen at the cathode.
- $\Delta G^{\circ} = -nFE^{\circ}$.When E° is positive, ΔG° is negative indicative of a spontaneous process. When E° is negative, ΔG° is positive indicative of a non-spontaneous process. When E° is 0, then ΔG° is 0.
- Current, duration of electrolysis and charge on the ion affect the amount of product formed at the electrodes during electrolysis.
- Electroplating involves the electrolytic coating of an object with a metallic thin layer.

International-mindedness:

- Many electrochemical cells can act as energy sources alleviating the world's energy problems but some cells such as super-efficient microbial fuel cells (MFCs) (also termed biological fuel cells) can contribute to clean-up of the environment. How do national governments and the international community decide on research priorities for funding purposes?

Theory of knowledge:

- The SHE is an example of an arbitrary reference. Would our scientific knowledge be the same if we chose different references?

Utilization:

- Electroplating.
- Electrochemical processes in dentistry.
- Rusting of metals.

Syllabus and cross-curricular links:
Topics 1.2 and 1.3—problems involving Avogadro's constant, amount of substance and the ideal gas equation
Topic 9.1—redox processes

19.1 Electrochemical cells

Applications and skills:

- Calculation of cell potentials using standard electrode potentials.
- Prediction of whether a reaction is spontaneous or not using E° values.
- Determination of standard free-energy changes (ΔG°) using standard electrode potentials.
- Explanation of the products formed during the electrolysis of aqueous solutions.
- Perform lab experiments that could include single replacement reactions in aqueous solutions.
- Determination of the relative amounts of products formed during electrolytic processes.
- Explanation of the process of electroplating.

Guidance:

- Electrolytic processes to be covered in theory should include the electrolysis of aqueous solutions (eg sodium chloride, copper(II) sulfate etc) and water using both inert platinum or graphite electrodes and copper electrodes. Explanations should refer to E° values, nature of the electrode and concentration of the electrolyte.
- $\Delta G^{\circ} = -nFE^{\circ}$ is given in the data booklet in section 1.
- Faraday's constant = 96 500 C mol^{-1} is given in the data booklet in section 2.
- The term "cells in series" should be understood.

Topic 15.2—spontaneity of a reaction
Option C.6—Nernst equation
Biology option B.3—environmental protection; waste treatment and microbial fuel cells

Aims:

- **Aim 8**: Biological fuel cells can produce electrical energy to power electrical devices, houses, factories etc. They can assist in environmental clean-up. Microbial fuel cells (MFCs) powered by microbes in sewage can clean up sewage which may result in cost-free waste water treatment.

Additional higher level

Topic 20: Organic chemistry

12 hours

Essential idea: Key organic reaction types include nucleophilic substitution, electrophilic addition, electrophilic substitution and redox reactions. Reaction mechanisms vary and help in understanding the different types of reaction taking place.

20.1 Types of organic reactions

Nature of science:

Looking for trends and discrepancies—by understanding different types of organic reactions and their mechanisms, it is possible to synthesize new compounds with novel properties which can then be used in several applications. Organic reaction types fall into a number of different categories. (3.1)

Collaboration and ethical implications—scientists have collaborated to work on investigating the synthesis of new pathways and have considered the ethical and environmental implications of adopting green chemistry. (4.1, 4.5)

Understandings:

Nucleophilic Substitution Reactions:

- S_N1 represents a nucleophilic unimolecular substitution reaction and S_N2 represents a nucleophilic bimolecular substitution reaction. S_N1 involves a carbocation intermediate. S_N2 involves a concerted reaction with a transition state.
- For tertiary halogenoalkanes the predominant mechanism is S_N1 and for primary halogenoalkanes it is S_N2. Both mechanisms occur for secondary halogenoalkanes.
- The rate determining step (slow step) in an S_N1 reaction depends only on the concentration of the halogenoalkane, rate = *k*[halogenoalkane]. For S_N2, rate = *k*[halogenoalkane][nucleophile]. S_N2 is stereospecific with an inversion of configuration at the carbon.
- S_N2 reactions are best conducted using aprotic, non-polar solvents and S_N1 reactions are best conducted using protic, polar solvents.

Electrophilic Addition Reactions:

- An electrophile is an electron-deficient species that can accept electron pairs from a nucleophile. Electrophiles are Lewis acids.

International-mindedness:

- What role does green and sustainable chemistry, in relation to organic chemistry, play in a global context?

Utilization:

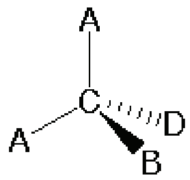
- Organic synthesis plays a vital role in drug design and drug uptake in medicine and biochemistry.
- Nutrition, food science and biotechnology also are underpinned by organic chemistry.

Syllabus and cross-curricular links:
Topics 10.1 and 10.2—organic chemistry
Topic 14.1—covalent bonding
Topic 14.2—hybridization
Option A.5 and A.9—polymers

Aims:

- **Aim 6**: Three-dimensional visualization of organic compounds using molecular models could be covered.

20.1 Types of organic reactions	
• Markovnikov's rule can be applied to predict the major product in electrophilic addition reactions of unsymmetrical alkenes with hydrogen halides and interhalogens. The formation of the major product can be explained in terms of the relative stability of possible carbocations in the reaction mechanism. *Electrophilic Substitution Reactions:* • Benzene is the simplest aromatic hydrocarbon compound (or arene) and has a delocalized structure of π bonds around its ring. Each carbon to carbon bond has a bond order of 1.5. Benzene is susceptible to attack by electrophiles. *Reduction Reactions:* • Carboxylic acids can be reduced to primary alcohols (via the aldehyde). Ketones can be reduced to secondary alcohols. Typical reducing agents are lithium aluminium hydride (used to reduce carboxylic acids) and sodium borohydride. **Applications and skills:** *Nucleophilic Substitution Reactions:* • Explanation of why hydroxide is a better nucleophile than water. • Deduction of the mechanism of the nucleophilic substitution reactions of halogenoalkanes with aqueous sodium hydroxide in terms of S_N1 and S_N2 mechanisms. Explanation of how the rate depends on the identity of the halogen (ie the leaving group), whether the halogenoalkane is primary, secondary or tertiary and the choice of solvent. • Outline of the difference between protic and aprotic solvents. *Electrophilic Addition Reactions:* • Deduction of the mechanism of the electrophilic addition reactions of alkenes with halogens/interhalogens and hydrogen halides.	• **Aim 6**: A range of experiments of organic synthetic reactions exploring various types of reactions and functional group interconversions could be done. Core techniques of organic chemistry could include reflux, distillation, filtration, purification (including chromatographic techniques), separations and extractions. • **Aim 6**: Synthesis (or reaction) in the laboratory of an example of a widely used drug or medicine (eg aspirin) or a household product (eg fading of tomato ketchup—electrophilic addition reaction of bromine).

20.1 Types of organic reactions	
Electrophilic Substitution Reactions: • Deduction of the mechanism of the nitration (electrophilic substitution) reaction of benzene (using a mixture of concentrated nitric acid and sulfuric acid). *Reduction Reactions:* • Writing reduction reactions of carbonyl containing compounds: aldehydes and ketones to primary and secondary alcohols and carboxylic acids to aldehydes, using suitable reducing agents. • Conversion of nitrobenzene to phenylamine via a two-stage reaction. **Guidance:** • Reference should be made to heterolytic fission for S_N1 reactions. • The difference between homolytic and heterolytic fission should be understood. • The difference between curly arrows and fish-hooks in reaction mechanisms should be emphasized. • Use of partial charges (δ+ and δ-) and wedge-dash three-dimensional representations (using tapered bonds as shown below) should be encouraged where appropriate in explaining reaction mechanisms.  • Typical conditions and reagents of all reactions should be known (eg catalysts, reducing agents, reflux etc.). However, more precise details such as specific temperatures need not be included.	

Essential idea: Organic synthesis is the systematic preparation of a compound from a widely available starting material or the synthesis of a compound via a synthetic route that often can involve a series of different steps.

<table>
<tr><td colspan="2">20.2 Synthetic routes</td></tr>
<tr><td colspan="2">Nature of science:
Scientific method—in synthetic design, the thinking process of the organic chemist is one which invokes retro-synthesis and the ability to think in a reverse-like manner. (1.3)</td></tr>
<tr><td>Understandings:
• The synthesis of an organic compound stems from a readily available starting material via a series of discrete steps. Functional group interconversions are the basis of such synthetic routes.
• Retro-synthesis of organic compounds.
Applications and skills:
• Deduction of multi-step synthetic routes given starting reagents and the product(s).
Guidance:
• Conversions with more than four stages will not be assessed in synthetic routes.
• Reaction types can cover any of the reactions covered in topic 10 and sub-topic 20.1.</td><td>International-mindedness:
• How important are natural products to developing countries? Explore some specific examples of natural products available in developing countries which are important to the developed world.
Theory of knowledge:
• A retro-synthetic approach is often used in the design of synthetic routes. What are the roles of imagination, intuition and reasoning in finding solutions to practical problems?
Utilization:
• Natural products are compounds isolated from natural sources and include taxol, mescaline and capsaicin.
Syllabus and cross-curricular links:
Topics 10.1 and 10.2—organic chemistry
Aims:
• Aim 6: Multiple stage organic synthetic route series of experiments (up to a maximum of four stages).</td></tr>
</table>

Essential idea: Stereoisomerism involves isomers which have different arrangements of atoms in space but do not differ in connectivity or bond multiplicity (ie whether single, double or triple) between the isomers themselves.

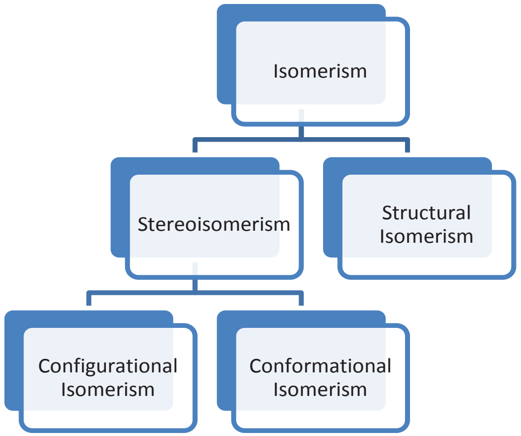
20.3 Stereoisomerism

Nature of science:

Transdisciplinary—the three-dimensional shape of an organic molecule is the foundation pillar of its structure and often its properties. Much of the human body is chiral. (4.1)

Understandings:

- Stereoisomers are subdivided into two classes—conformational isomers, which interconvert by rotation about a σ bond and configurational isomers that interconvert only by breaking and reforming a bond.



Configurational isomers are further subdivided into cis-trans and E/Z isomers and optical isomers.

International-mindedness:

- Have drugs and medicines in some countries been sold and administered as racemates instead of as the desired enantiomer with the associated therapeutic activity? Can you think of any drugs or medicines which may serve as good case studies for this?

Theory of knowledge:

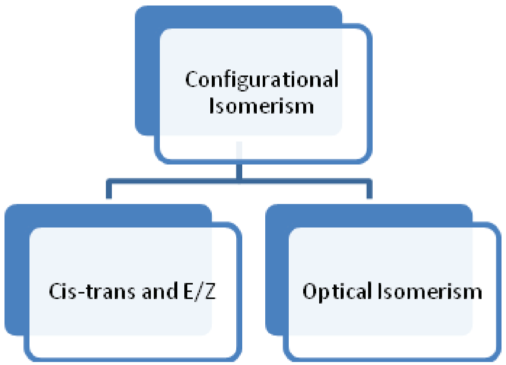
- The existence of optical isomers provide indirect evidence for a tetrahedrally bonded carbon atom. Which ways of knowing allow us to connect indirect evidence to our theories?
- Stereoisomerism can be investigated by physical and computer models. What is the role of such models in other areas of knowledge?
- One of the challenges for the scientist and the artist is to represent the three-dimensional world in two dimensions. What are the similarities and differences in the two approaches? What is the role of the different ways of knowing in the two approaches?

Utilization:

- Many of the drugs derived from natural sources are chiral and include nicotine, dopamine, thyroxine and naproxen.
- The role of stereochemistry in vision science and food science.
- In many perfumes, stereochemistry often can be deemed more important than chemical composition.

Syllabus and cross-curricular links:

20.3 Stereoisomerism



- Cis-trans isomers can occur in alkenes or cycloalkanes (or heteroanalogues) and differ in the positions of atoms (or groups) relative to a reference plane. According to IUPAC, E/Z isomers refer to alkenes of the form R1R2C=CR3R4 (R1 ≠ R2, R3 ≠ R4) where neither R1 nor R2 need be different from R3 or R4.
- A chiral carbon is a carbon joined to four different atoms or groups.
- An optically active compound can rotate the plane of polarized light as it passes through a solution of the compound. Optical isomers are enantiomers. Enantiomers are non-superimposeable mirror images of each other. Diastereomers are not mirror images of each other.
- A racemic mixture (or racemate) is a mixture of two enantiomers in equal amounts and is optically inactive.

Applications and skills:

- Construction of 3-D models (real or virtual) of a wide range of stereoisomers.
- Explanation of stereoisomerism in non-cyclic alkenes and C3 and C4 cycloalkanes.

Topics 10.1 and 10.2—organic chemistry
Option B.4—carbohydrates
Option B.10—stereochemistry in biomolecules
Option D.7—importance of chirality and drug action

Aims

- **Aim 6**: Experiments could include the synthesis and characterization of an enantiomer (eg (-) menthol) or the resolution of a racemic mixture.

20.3 Stereoisomerism	
• Comparison between the physical and chemical properties of enantiomers. • Description and explanation of optical isomers in simple organic molecules. • Distinction between optical isomers using a polarimeter. **Guidance:** • The term geometric isomers as recommended by IUPAC is now obsolete and cis-trans isomers and E/Z isomers should be encouraged in the teaching programme. • In the E/Z system, the group of highest Cahn–Ingold–Prelog priority attached to one of the terminal doubly bonded atoms of the alkene (ie R1 or R2) is compared with the group of highest precedence attached to the other (ie R3 or R4). The stereoisomer is Z if the groups lie on the same side of a reference plane passing through the double bond and perpendicular to the plane containing the bonds linking the groups to the double-bonded atoms; the other stereoisomer is designated as E. • Wedge-dash type representations involving tapered bonds should be used for representations of optical isomers.	

Topic 21: Measurement and analysis

2 hours

Essential idea: Although spectroscopic characterization techniques form the backbone of structural identification of compounds, typically no one technique results in a full structural identification of a molecule.

<table>
<tr><td colspan="2">21.1 Spectroscopic identification of organic compounds</td></tr>
<tr><td colspan="2">Nature of science:
Improvements in modern instrumentation—advances in spectroscopic techniques (IR, ^{1}H NMR and MS) have resulted in detailed knowledge of the structure of compounds. (1.8)</td></tr>
<tr><td>Understandings:
• Structural identification of compounds involves several different analytical techniques including IR, ^{1}H NMR and MS.
• In a high resolution ^{1}H NMR spectrum, single peaks present in low resolution can split into further clusters of peaks.
• The structural technique of single crystal X-ray crystallography can be used to identify the bond lengths and bond angles of crystalline compounds.
Applications and skills:
• Explanation of the use of tetramethylsilane (TMS) as the reference standard.
• Deduction of the structure of a compound given information from a range of analytical characterization techniques (X-ray crystallography, IR, ^{1}H NMR and MS).
Guidance:
• Students should be able to interpret the following from ^{1}H NMR spectra: number of peaks, area under each peak, chemical shift and splitting patterns. Treatment of spin-spin coupling constants will not be assessed but students should be familiar with singlets, doublets, triplets and quartets.
• High resolution ^{1}H NMR should be covered.</td>
<td>International-mindedness:
• The chemical community often shares chemical structural information on the international stage. The Cambridge Crystallographic Database, ChemSpider developed by the Royal Society of Chemistry and the Protein Data Bank (RCSB PDB) (at Brookhaven National Laboratory, USA) are examples which highlight the international nature of the scientific community.
Theory of knowledge:
• The intensity ratio of the lines in the high resolution NMR spectrum is given by the numbers in Pascal's triangle, a mathematical pattern known independently over a thousand years ago by a number of different cultures. Why is mathematics such an effective tool in science? Is mathematics the science of patterns?
Utilization:
• Protons in water molecules within human cells can be detected by magnetic resonance imaging (MRI), giving a three-dimensional view of organs in the human body. Why is MRI replacing computerized tomography (CT) scans for some applications but is used as a complementary technique for others?
• MS (and other techniques such as TLC, GC, GC-MS and HPLC) can be used in forensic investigations at crime scenes.
• Analytical techniques can be used to test for drug abuse by high-performance athletes.</td></tr>
</table>

21.1 Spectroscopic identification of organic compounds	
• The precise details of single crystal X-ray crystallography need not be known in detail, but students should be aware of the existence of this structural technique in the wider context of structural identification of both inorganic and organic compounds. • The operating principles are not required for any of these methods.	Syllabus and cross-curricular links: Topic 11.3—spectroscopic identification of compounds Option B.2—chromatography and protein separation Option B.9—chromatography and pigments Option D.7—chiral auxiliaries **Aims:** • **Aim 7**: Spectral databases can be used here.

Core topics

Essential idea: Materials science involves understanding the properties of a material, and then applying those properties to desired structures.

A.1 Materials science introduction	
Nature of science: Improvements in technology—different materials were used for different purposes before the development of a scientific understanding of their properties. (1.8) Patterns in science—history has characterized civilizations by the materials they used: Stone Age, Bronze Age and Iron Age. There are various ways of classifying materials according to desired patterns. (3.1)	
Understandings: • Materials are classified based on their uses, properties, or bonding and structure. • The properties of a material based on the degree of covalent, ionic or metallic character in a compound can be deduced from its position on a bonding triangle. • Composites are mixtures in which materials are composed of two distinct phases, a reinforcing phase that is embedded in a matrix phase. **Applications and skills:** • Use of bond triangle diagrams for binary compounds from electronegativity data. • Evaluation of various ways of classifying materials. • Relating physical characteristics (melting point, permeability, conductivity, elasticity, brittleness) of a material to its bonding and structures (packing arrangements, electron mobility, ability of atoms to slide relative to one another).	**International-mindedness:** • What materials were used by ancient civilizations, such as the Aztecs, Romans, and Chinese? Even though these ancient civilizations were located in geographically diverse locations, the materials they used were similar. **Theory of knowledge:** • Although it is convenient to classify materials into categories no single classification is “perfect”. How do we evaluate the different classification systems we use in the different areas of knowledge? How does our need to categorize the world help and hinder the pursuit of knowledge? **Utilization:** Syllabus and cross-curricular links: Topic 4.2—the role of electronegativity in bonding types

A.1 Materials science introduction	
Guidance: • Permeability to moisture should be considered with respect to bonding and simple packing arrangements. • Consider properties of metals, polymers and ceramics in terms of metallic, covalent, and ionic bonding. • See section 29 of the data booklet for a triangular bonding diagram.	**Aims:** • **Aims 1** and **3**: Investigation of tetrahedra of structure and bonding types and where covalent networks and polymers fit on these diagrams. • **Aim 6**: Experiments could include investigating the stretching of rubber bands under different chemical environments, or properties of metals, polymers, ceramics, or composites, making thin concrete slabs from various ratios of cement, gravel, and sand and investigating the breaking strength upon drying.

Essential idea: Metals can be extracted from their ores and alloyed for desired characteristics. ICP-MS/OES Spectroscopy ionizes metals and uses mass and emission spectra for analysis.

<table>
<tr><td colspan="2">A.2 Metals and inductively coupled plasma (ICP) spectroscopy</td></tr>
<tr><td colspan="2">Nature of science:
Development of new instruments and techniques—ICP spectroscopy, developed from an understanding of scientific principles, can be used to identify and quantify trace amounts of metals. (1.8)
Details of data—with the discovery that trace amounts of certain materials can greatly enhance a metal's performance, alloying was initially more of an art than a science. (3.1)</td></tr>
<tr><td>Understandings:
• Reduction by coke (carbon), a more reactive metal, or electrolysis are means of obtaining some metals from their ores.
• The relationship between charge and the number of moles of electrons is given by Faraday's constant, F.
• Alloys are homogeneous mixtures of metals with other metals or non-metals.
• Diamagnetic and paramagnetic compounds differ in electron spin pairing and their behaviour in magnetic fields.
• Trace amounts of metals can be identified and quantified by ionizing them with argon gas plasma in Inductively Coupled Plasma (ICP) Spectroscopy using Mass Spectroscopy ICP-MS and Optical Emission Spectroscopy ICP-OES.
Applications and skills:
• Deduction of redox equations for the reduction of metals.
• Relating the method of extraction to the position of a metal on the activity series.
• Explanation of the production of aluminium by the electrolysis of alumina in molten cryolite
• Explanation of how alloying alters properties of metals.</td>
<td>International-mindedness:
• The use of rare earth metals, or exotic minerals, has grown dramatically. They are used in green technology, medicines, lasers, weapons technology and elsewhere. They are expensive to obtain but growing in demand. What happens if rare earth reserves are controlled only by a few countries but are used by many countries?
Theory of knowledge:
• What factors/outcomes should be used to determine how time, money, and effort is spent on scientific research? Who decides which knowledge is to be pursued?
Utilization:
Syllabus and cross-curricular links:
Topics 2.1 and 12.1—mass spectrometry
Topic 2.2—emission spectra
Topic 9.1—oxidation and reduction
Aims:
• Aim 6: Experiments could include calculating the Faraday constant via electrolysis of aqueous copper sulfate, solving for the concentration of a nickel or copper solution using Beer's law and spectrophotometry. Analysis of alloy composition labs could also be conducted such as colorimetric determination of manganese in a paper clip or gravimetric analysis of silver or copper in a coin.</td></tr>
</table>

A.2 Metals and inductively coupled plasma (ICP) spectroscopy	
• Solving stoichiometric problems using Faraday's constant based on mass deposits in electrolysis. • Discussion of paramagnetism and diamagnetism in relation to electron structure of metals. • Explanation of the plasma state and its production in ICP- MS/OES. • Identify metals and abundances from simple data and calibration curves provided from ICP-MS and ICP-OES. • Explanation of the separation and quantification of metallic ions by MS and OES. • Uses of ICP-MS and ICP-OES. **Guidance:** • Faraday's constant is given in the data booklet in section 2. • Details of operating parts of ICP-MS and ICP-OES instruments will not be assessed. • Only analysis of metals should be covered. • The importance of calibration should be covered.	• **Aim 7**: Animations involving ICP could be used. • **Aim 7**: Simulations and virtual experiments could be used to investigate semiconductors.

Essential idea: Catalysts work by providing an alternate reaction pathway for the reaction. Catalysts always increase the rate of the reaction and are left unchanged at the end of the reaction.

A.3 Catalysts

Nature of science:

Use of models—catalysts were used to increase reaction rates before the development of an understanding of how they work. This led to models that are constantly being tested and improved. (1.10)

Understandings:

- Reactants adsorb onto heterogeneous catalysts at active sites and the products desorb.
- Homogeneous catalysts chemically combine with the reactants to form a temporary activated complex or a reaction intermediate.
- Transition metal catalytic properties depend on the adsorption/absorption properties of the metal and the variable oxidation states.
- Zeolites act as selective catalysts because of their cage structure.
- Catalytic particles are nearly always nanoparticles that have large surface areas per unit mass.

Applications and skills:

- Explanation of factors involved in choosing a catalyst for a process.
- Description of how metals work as heterogeneous catalysts.
- Description of the benefits of nanocatalysts in industry.

Guidance:

- Consider catalytic properties such as selectivity for only the desired product, efficiency, ability to work in mild/severe conditions, environmental impact and impurities.
- The use of carbon nanocatalysts should be covered.

International-mindedness:

- Palladium, platinum and rhodium are common catalysts that are used in catalytic converters. Because of the value of these metals, catalytic converter thefts are on the rise.

Theory of knowledge:

- Some materials used as effective catalysts are toxic and harmful to the environment. Is environmental degradation justified in the pursuit of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topics 6.1 and 16.1—reaction mechanisms
Topic 10.2—esterification and hydrogenation reactions
Topic 16.2—activation energy
Option B.10—hydrogenation of fats

Aims:

- **Aims 1** and **3**: Investigate various catalysts for both the benefits and risks.
- **Aim 6**: Experiments could include investigating the decomposition of potassium sodium tartrate with cobalt chloride and the decomposition of hydrogen peroxide with manganese (IV) oxide.
- **Aim 6**: An ion exchange using zeolite could be explored.
- **Aim 7**: Virtual experiments and simulations involving nanoparticles as catalysts could be done here.

Essential idea: Liquid crystals are fluids that have physical properties which are dependent on molecular orientation relative to some fixed axis in the material.

A.4 Liquid crystals

Nature of science

Serendipity and scientific discoveries—Friedrich Reinitzer accidently discovered flowing liquid crystals in 1888 while experimenting on cholesterol. (1.4)

Understandings:

- Liquid crystals are fluids that have physical properties (electrical, optical and elasticity) that are dependent on molecular orientation to some fixed axis in the material.
- Thermotropic liquid-crystal materials are pure substances that show liquid-crystal behaviour over a temperature range.
- Lyotropic liquid crystals are solutions that show the liquid-crystal state over a (certain) range of concentrations.
- Nematic liquid crystal phase is characterized by rod shaped molecules which are randomly distributed but on average align in the same direction.

Applications and skills:

- Discussion of the properties needed for a substance to be used in liquid-crystal displays (LCD).
- Explanation of liquid-crystal behaviour on a molecular level.

Guidance:

- Properties needed for liquid crystals include: chemically stable, a phase which is stable over a suitable temperature range, polar so they can change orientation when an electric field is applied, and rapid switching speed.
- Soap and water is an example of lyotropic liquid crystals and the biphenyl nitriles are examples of thermotropic liquid crystals.
- Liquid crystal behaviour should be limited to the biphenyl nitriles.
- Smectics and other liquid crystals types need not be discussed.

International-mindedness:

- The production of many electronic goods is concentrated in areas of the world where the working conditions may not be ideal. Should there be internationally set labour standards for all workers? What implications would this have on the cost of consumer goods?

Theory of knowledge:

- Developments in technology mean that we can store more and more information available on an increasingly smaller scale. Does this mean that we can access more knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 20.3—chirality and stereoisomers

Aims:

- **Aim 6**: Experiments could include investigating a thermotropic liquid crystal and the temperature range which affects these crystals.
- **Aim 7**: Computer animations could be used to investigate thermotropic liquid crystals.

Essential idea: Polymers are made up of repeating monomer units which can be manipulated in various ways to give structures with desired properties.

A.5 Polymers

Nature of science:

Advances in technology—as a result of advances in technology (X-ray diffraction, scanning tunnelling electron microscopes, etc), scientists have been able to understand what occurs on the molecular level and manipulate matter in new ways. This allows new polymers to be developed. (3.7)

Theories can be superseded—Staudinger's proposal of macromolecules made of many repeating units was integral in the development of polymer science. (1.9)

Ethics and risk assessment—polymer development and use has grown quicker than an understanding of the risks involved, such as recycling or possible carcinogenic properties. (4.5)

Understandings:

- Thermoplastics soften when heated and harden when cooled.
- A thermosetting polymer is a prepolymer in a soft solid or viscous state that changes irreversibly into a hardened thermoset by curing.
- Elastomers are flexible and can be deformed under force but will return to nearly their original shape once the stress is released.
- High density polyethene (HDPE) has no branching allowing chains to be packed together.
- Low density polyethene (LDPE) has some branching and is more flexible.
- Plasticizers added to a polymer increase the flexibility by weakening the intermolecular forces between the polymer chains.
- Atom economy is a measure of efficiency applied in green chemistry.
- Isotactic addition polymers have substituents on the same side.
- Atactic addition polymers have the substituents randomly placed.

Applications and skills:

- Description of the use of plasticizers in polyvinyl chloride and volatile hydrocarbons in the formation of expanded polystyrene.

International-mindedness:

- Plastics were virtually unheard of prior to the second world war. How has the introduction of plastics affected the world economically, socially and environmentally?

Utilization:

Syllabus and cross-curricular links:
Topics 10.2 and 20.1—addition and condensation reactions

Aims:

- **Aim 6**: Physical properties of high and low density polyethene could be investigated or synthesis of a polyester, polyamide or other polymer could be quantitatively performed to measure atom efficiency.

A.5 Polymers	
• Solving problems and evaluating atom economy in synthesis reactions. • Description of how the properties of polymers depend on their structural features. • Description of ways of modifying the properties of polymers, including LDPE and HDPE. • Deduction of structures of polymers formed from polymerizing 2-methylpropene. **Guidance:** • The equation for percent atom economy is provided in the data booklet in section 1. • Consider only polystyrene foams as examples of polymer property manipulation.	

Essential idea: Chemical techniques position atoms in molecules using chemical reactions whilst physical techniques allow atoms/molecules to be manipulated and positioned to specific requirements.

A.6 Nanotechnology

Nature of science:

Improvements in apparatus—high power electron microscopes have allowed for the study of positioning of atoms. (1.8)

The need to regard theories as uncertain—the role of trial and error in the development of nanotubes and their associated theories. (2.2)

"The principles of physics, as far as I can see, do not speak against the possibility of manoeuvring things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big."
— Richard Feynman, Nobel Prize winner in Physics

Understandings:

- Molecular self-assembly is the bottom-up assembly of nanoparticles and can occur by selectively attaching molecules to specific surfaces. Self-assembly can also occur spontaneously in solution.
- Possible methods of producing nanotubes are arc discharge, chemical vapour deposition (CVD) and high pressure carbon monoxide (HIPCO).
- Arc discharge involves either vaporizing the surface of one of the carbon electrodes, or discharging an arc through metal electrodes submersed in a hydrocarbon solvent, which forms a small rod-shaped deposit on the anode.

Applications and skills:

- Distinguishing between physical and chemical techniques in manipulating atoms to form molecules.
- Description of the structure and properties of carbon nanotubes.
- Explanation of why an inert gas, and not oxygen, is necessary for CVD preparation of carbon nanotubes.
- Explanation of the production of carbon from hydrocarbon solvents in arc discharge by oxidation at the anode.
- Deduction of equations for the production of carbon atoms from HIPCO.

International-mindedness:

- Some studies have shown that inhaling nanoparticle dust can be as harmful as asbestos. Should nanotechnology be regulated or will this hinder research?
- International collaboration in space exploration is growing. Would a carbon nanotube space elevator be feasible, or wanted? What are the implications?

Theory of knowledge:

- The use of the scanning tunnelling microscope has allowed us to "see" individual atoms, which was previously thought to be unattainable. How do these advances in technology change our view of what knowledge is attainable?
- Some people are concerned about the possible implication of nanotechnology. How do we evaluate the possible consequences of future developments in this area? Is the knowledge we need publicly available or do we rely on the authority of experts?

Utilization:

- Protein synthesis in cells is a form of nanotechnology with ribosomes acting as molecular assemblers.

Syllabus and cross-curricular links:
Topics 4.3—molecular polarity

A.6 Nanotechnology	
• Discussion of some implications and applications of nanotechnology. • Explanation of why nanotubes are strong and good conductors of electricity. **Guidance:** • Possible implications of nanotechnology include uncertainty as to toxicity levels on a nanoscale, unknown health risks with new materials, concern that human defence systems are not effective against particles on the nanoscale, responsibilities of the industries and governments involved in this research. • Conductivity of graphene and fullerenes can be explained in terms of delocalization of electrons. An explanation based on hybridization is not required.	**Aims:** • **Aims 1**, **8** and **9**: Investigate the theoretical and large scale manufacturing of nanotechnology products and their implications. Examples could include sporting equipment, medicinal products, construction, environmental cleaning, robotics, weaponry or other theoretical commercial uses. • **Aims 7**, **8** and **9**: Animations, simulations, and videos of nanotube manufacture and uses should be used.

Essential idea: Although materials science generates many useful new products there are challenges associated with recycling of and high levels of toxicity of some of these materials.

A.7 Environmental impact—plastics	
Nature of science: Risks and problems—scientific research often proceeds with perceived benefits in mind, but the risks and implications also need to be considered. (4.8)	
Understandings: • Plastics do not degrade easily because of their strong covalent bonds. • Burning of polyvinyl chloride releases dioxins, HCl gas and incomplete hydrocarbon combustion products. • Dioxins contain unsaturated six-member heterocyclic rings with two oxygen atoms, usually in positions 1 and 4. • Chlorinated dioxins are hormone disrupting, leading to cellular and genetic damage. • Plastics require more processing to be recycled than other materials. • Plastics are recycled based on different resin types. **Applications and skills:** • Deduction of the equation for any given combustion reaction. • Discussion of why the recycling of polymers is an energy intensive process. • Discussion of the environmental impact of the use of plastics. • Comparison of the structures of polychlorinated biphenyls (PCBs) and dioxins. • Discussion of the health concerns of using volatile plasticizers in polymer production. • Distinguish possible Resin Identification Codes (RICs) of plastics from an IR spectrum.	**International-mindedness:** • The international symbol for recycle, reuse and reduce is a Mobius strip designed in the late 1960s. However, global recognition of this symbol ranks well below other symbols. What factors influence the recognition of symbols? • How can nations address the problem of the plastic gyre in the Pacific Ocean? **Theory of knowledge:** • The products of science and technology can have a negative impact on the environment. Are scientists ethically responsible for the impact of their products? **Utilization:** Syllabus and cross-curricular links: Topic 9.1—redox reactions Topic 10.1—organic compounds Topic 11.3—infrared spectroscopy Biology option C.3—impact of humans on ecosystems **Aims:** • **Aim 7**: Database of RIC codes and IR spectra can be used. • **Aim 8**: The development of green chemistry has raised the awareness of the environmental and the ethical implications of using science and technology.

A.7 Environmental impact—plastics	
Guidance: • Dioxins do not decompose in the environment and can be passed on in the food chain. • Consider polychlorinated dibenzodioxins (PCDD) and PCBs as examples of carcinogenic chlorinated dioxins or dioxin-like substances. • Consider phthalate esters as examples of plasticizers. • House fires can release many toxins due to plastics (shower curtains, etc). Low smoke zero halogen cabling is often used in wiring to prevent these hazards. • Resin Identification Codes (RICs) are in the data booklet in section 30. • Structures of various materials molecules are in the data booklet in section 31.	

Additional higher level topics

Essential idea: Superconductivity is zero electrical resistance and expulsion of magnetic fields. X-ray crystallography can be used to analyse structures.

A.8 Superconducting metals and X-ray crystallography

Nature of science:

Importance of theories—superconducting materials, with zero electrical resistance below a certain temperature, provide a good example of theories needing to be modified to fit new data. It is important to understand the basic scientific principles behind modern instruments. (2.2)

Understandings:

- Superconductors are materials that offer no resistance to electric currents below a critical temperature.
- The Meissner effect is the ability of a superconductor to create a mirror image magnetic field of an external field, thus expelling it.
- Resistance in metallic conductors is caused by collisions between electrons and positive ions of the lattice.
- The Bardeen–Cooper–Schrieffer (BCS) theory explains that below the critical temperature electrons in superconductors form Cooper pairs which move freely through the superconductor.
- Type 1 superconductors have sharp transitions to superconductivity whereas Type 2 superconductors have more gradual transitions.
- X-ray diffraction can be used to analyse structures of metallic and ionic compounds.
- Crystal lattices contain simple repeating unit cells.
- Atoms on faces and edges of unit cells are shared.
- The number of nearest neighbours of an atom/ion is its coordination number.

International-mindedness:

- Analytical techniques have applications in forensics, mineral exploration, medicine and elsewhere. How does the unequal access to advanced technology affect world economies?

Theory of knowledge:

- X-ray diffraction has allowed us to probe the world beyond the biological limits of our senses. How reliable is our knowledge of the microscopic world compared to what we know at the macroscopic level?

Utilization:

Syllabus and cross-curricular links:
Topic 2.2—Pauli exclusion principle
Topic 3.2—atomic radius and periodicity
Topic 21.1—X-ray crystallography
Physics topic 4.2—travelling waves

Aims:

- **Aim 7**: Animations and simulations would be very useful to explain superconductivity and X-ray crystallography.

A.8 Superconducting metals and X-ray crystallography	
Applications and skills: • Analysis of resistance versus temperature data for Type 1 and Type 2 superconductors. • Explanation of superconductivity in terms of Cooper pairs moving through a positive ion lattice. • Deduction or construction of unit cell structures from crystal structure information. • Application of the Bragg equation, $n\lambda = 2dsin\theta$, in metallic structures. • Determination of the density of a pure metal from its atomic radii and crystal packing structure. **Guidance:** • Only a simple explanation of BCS theory with Cooper pairs is required. At low temperatures the positive ions in the lattice are distorted slightly by a passing electron. A second electron is attracted to this slight positive deformation and a coupling of these two electrons occurs. • Operating principles of X-ray crystallography are not required. • Only pure metals with simple cubic cells, body centred cubic cells (BCC) and face centred cubic cells (FCC) should be covered. • Perovskite crystalline structures of many superconductors can be analysed by X-ray crystallography but these will not be assessed. • Bragg's equation will only be applied to simple cubic structures.	

Essential idea: Condensation polymers are formed by the loss of small molecules as functional groups from monomers join.

A.9 Condensation polymers	
Nature of science: Speculation—we have had the Stone Age, Iron Age and Bronze Age. Is it possible that today's age is the Age of Polymers, as science continues to manipulate matter for desired purposes? (1.5)	
Understandings: • Condensation polymers require two functional groups on each monomer. • NH_3, HCl and H_2O are possible products of condensation reactions. • Kevlar® is a polyamide with a strong and ordered structure. The hydrogen bonds between O and N can be broken with the use of concentrated sulfuric acid. **Applications and skills:** • Distinguishing between addition and condensation polymers. • Completion and descriptions of equations to show how condensation polymers are formed. • Deduction of the structures of polyamides and polyesters from their respective monomers. • Explanation of Kevlar®'s strength and its solubility in concentrated sulfuric acid. **Guidance:** • Consider green chemistry polymers.	**International-mindedness:** • Does science, economics or politics play the most essential role in research, such as the development of new polymers? **Utilization:** Syllabus and cross-curricular links: Topic 10.2—addition and condensation reactions Topic 20.2—synthesis techniques Option A.5—polymers **Aims:** • **Aim 6**: Synthesis of nylon could be performed.

Essential idea: Toxicity and carcinogenic properties of heavy metals are the result of their ability to form coordinated compounds, have various oxidation states and act as catalysts in the human body.

A.10 Environmental impact—heavy metals	
Nature of science: Risks and problems—scientific research often proceeds with perceived benefits in mind, but the risks and implications also need to be considered. (4.8)	
Understandings: • Toxic doses of transition metals can disturb the normal oxidation/reduction balance in cells through various mechanisms. • Some methods of removing heavy metals are precipitation, adsorption, and chelation. • Polydentate ligands form more stable complexes than similar monodentate ligands due to the chelate effect, which can be explained by considering entropy changes. **Applications and skills:** • Explanation of how chelating substances can be used to remove heavy metals. • Deduction of the number of coordinate bonds a ligand can form with a central metal ion. • Calculations involving K_{sp} as an application of removing metals in solution. • Compare and contrast the Fenton and Haber–Weiss reaction mechanism. **Guidance:** • Ethane-1,2-diamine acts as a bidentate ligand and $EDTA^{4-}$ acts as hexadentate ligand. • The Haber–Weiss reaction generates free radicals naturally in biological processes. Transition metals can catalyse the reaction with the iron-catalysed (Fenton) reaction being the mechanism for generating reactive hydroxyl radicals. • K_{sp} values are in the data booklet in section 32.	**Theory of knowledge:** • What responsibility do scientists have for the impact of their endeavours on the planet? **Utilization:** Syllabus and cross-curricular links: Topic 9.1—redox reactions Topic 13.2—transition metal complexes Biology option C.3—impact of humans on ecosystems **Aims:** • **Aims 1** and **8**: Investigations of waste water treatment. • **Aim 6**: Experiments could include investigations of K_{sp}.

Core topics

Essential idea: Metabolic reactions involve a complex interplay between many different components in highly controlled environments.

B.1 Introduction to biochemistry

Nature of science:

Use of data—biochemical systems have a large number of different reactions occurring in the same place at the same time. As technologies have developed, more data has been collected leading to the discovery of patterns of reactions in metabolism. (3.1)

Understandings:

- The diverse functions of biological molecules depend on their structures and shapes.
- Metabolic reactions take place in highly controlled aqueous environments.
- Reactions of breakdown are called catabolism and reactions of synthesis are called anabolism.
- Biopolymers form by condensation reactions and are broken down by hydrolysis reactions.
- Photosynthesis is the synthesis of energy-rich molecules from carbon dioxide and water using light energy.
- Respiration is a complex set of metabolic processes providing energy for cells.

Applications and skills :

- Explanation of the difference between condensation and hydrolysis reactions.
- The use of summary equations of photosynthesis and respiration to explain the potential balancing of oxygen and carbon dioxide in the atmosphere.

Guidance:

- Intermediates of aerobic respiration and photosynthesis are not required.

International-mindedness:

- Metabolic reactions in the human body are dependent on the supply of nutrients through a regular balanced diet. Globally there are significant differences in the availability of nutritious food, which have major and diverse impacts on human health.

Utilization:

- Biochemistry is fundamental to the study of many other subjects, including genetics, immunology, pharmacology, nutrition and agriculture.

Syllabus and cross-curricular links:
Topic 10.2—S_N reactions (condensation and hydrolysis)
Topic 13.2 and Option B.9—metal complexes and light absorption
Option C.8—electronic conjugation and light absorption

Essential idea: Proteins are the most diverse of the biopolymers responsible for metabolism and structural integrity of living organisms.

B.2 Proteins and enzymes

Nature of science:

Collaboration and peer review—several different experiments on several continents led to the conclusion that DNA, and not protein as originally thought, carried the information for inheritance. (4.4)

Understandings:

- Proteins are polymers of 2-amino acids, joined by amide links (also known as peptide bonds).
- Amino acids are amphoteric and can exist as zwitterions, cations and anions.
- Protein structures are diverse and are described at the primary, secondary, tertiary and quaternary levels.
- A protein's three-dimensional shape determines its role in structural components or in metabolic processes.
- Most enzymes are proteins that act as catalysts by binding specifically to a substrate at the active site.
- As enzyme activity depends on the conformation, it is sensitive to changes in temperature and pH and the presence of heavy metal ions.
- Chromatography separation is based on different physical and chemical principles.

Applications and skills:

- Deduction of the structural formulas of reactants and products in condensation reactions of amino acids, and hydrolysis reactions of peptides.
- Explanation of the solubilities and melting points of amino acids in terms of zwitterions.
- Application of the relationships between charge, pH and isoelectric point for amino acids and proteins.

International-mindedness:

- The Universal Protein Resource (UniProt) is a consortium of bioinformatics institutes. Its mission is to act as a resource for the scientific community by providing comprehensive, high-quality and freely accessible data on protein sequence and functional information.

Utilization:

- Many synthetic materials are polyamides. Examples include nylon and Kevlar®.
- Electrophoresis is used in some medical diagnostics to identify patterns of unusual protein content in blood serum or urine.
- The first protein to be sequenced was insulin by Frederick Sanger in 1951, in a process that took over ten years. Today, protein sequencing is a routine and very efficient process, and is a major part of the study known as proteomics.

Syllabus and cross-curricular links:
Topics 8.3 and 18.2—pH and pK_a and pK_b values
Topic 20.3—stereoisomerism
Option A.9—condensation polymers
Option B.9—chromatography
Biology topics 2.4, 2.5 and 8.1—proteins and enzymes

Aims:

- **Aim 6**: Experiments could involve hydrolysis of a protein, separation and identification of amino acid mixtures by paper chromatography, or gel electrophoresis of proteins and DNA.
- **Aim 7**: Data logging experiments involving absorption/concentration studies for protein content using the Biuret reagent.

B.2 Proteins and enzymes	
• Description of the four levels of protein structure, including the origin and types of bonds and interactions involved. • Deduction and interpretation of graphs of enzyme activity involving changes in substrate concentration, pH and temperature. • Explanation of the processes of paper chromatography and gel electrophoresis in amino acid and protein separation and identification. **Guidance:** • The names and structural formulas of the amino acids are given in the data booklet in section 33. • Reference should be made to alpha helix and beta pleated sheet, and to fibrous and globular proteins with examples of each. • In paper chromatography the use of R_f values and locating agents should be covered. • In enzyme kinetics K_m and V_{max} are not required.	• **Aim 7**: Simulations can be used for gel electrophoresis.

Essential idea: Lipids are a broad group of biomolecules that are largely non-polar and therefore insoluble in water.

B.3 Lipids

Nature of science:

Significance of science explanations to the public—long-term studies have led to knowledge of the negative effects of diets high in saturated fat, cholesterol, and *trans*-fat. This has led to new food products. (5.2)

Understandings:

- Fats are more reduced than carbohydrates and so yield more energy when oxidized.
- Triglycerides are produced by condensation of glycerol with three fatty acids and contain ester links. Fatty acids can be saturated, monounsaturated or polyunsaturated.
- Phospholipids are derivatives of triglycerides.
- Hydrolysis of triglycerides and phospholipids can occur using enzymes or in alkaline or acidic conditions.
- Steroids have a characteristic fused ring structure, known as a steroidal backbone.
- Lipids act as structural components of cell membranes, in energy storage, thermal and electrical insulation, as transporters of lipid soluble vitamins and as hormones.

Applications and skills:

- Deduction of the structural formulas of reactants and products in condensation and hydrolysis reactions between glycerol and fatty acids and/or phosphate.
- Prediction of the relative melting points of fats and oils from their structures.
- Comparison of the processes of hydrolytic and oxidative rancidity in fats with respect to the site of reactivity in the molecules and the conditions that favour the reaction.

International-mindedness:

- There are large global and cultural differences in the dietary sources of lipids and methods used to prevent rancidity.

Theory of knowledge:

- Different countries have very different standards towards food labelling. Is access to information a human right? What knowledge should be universally available?
- What are the different responsibilities of government, industry, the medical profession and the individual in making healthy choices about diet? Public bodies can protect the individual but also limit their freedom. How do we know what is best for society and the individual?

Utilization:

- Alkaline hydrolysis of fats is used in the process of soap-making, known as saponification.
- Steroid abuse, especially in sports, and methods for detection.

Syllabus and cross-curricular links:
Topics 10.1 and 10.2—functional groups, hydrogenation of alkenes
Topic 10.2—free radical mechanisms
Topic 20.3—configurational isomerism
Biology topic 2.3—lipids

B.3 Lipids

- Application of the concept of iodine number to determine the unsaturation of a fat.
- Comparison of carbohydrates and lipids as energy storage molecules with respect to their solubility and energy density.
- Discussion of the impact of lipids on health, including the roles of dietary high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol, saturated, unsaturated and *trans*-fat and the use and abuse of steroids.

Guidance:

- The structures of some fatty acids are given in the data booklet in section 34.
- Specific named examples of fats and oils do not have to be learned.
- The structural differences between *cis*- and *trans*-fats are not required.

Aims:

- **Aim 6**: Experiments could include the calculation of the iodine number of fats to measure degree of unsaturation, calorimetric experiments on different fats and oils, or the separation of lipids from common food sources using different solvents and a separating funnel.

Essential idea: Carbohydrates are oxygen-rich biomolecules, which play a central role in metabolic reactions of energy transfer.

B.4 Carbohydrates

Nature of science:

Construct models/visualizations—understanding the stereochemistry of carbohydrates is essential to understanding their structural roles in cells. Haworth projections help focus on the nature and position of attached groups by making carbon and hydrogen implicit. (1.10)

Obtaining evidence for scientific theories—consider the structural role of carbohydrates. (1.8)

Understandings:

- Carbohydrates have the general formula $C_x(H_2O)_y$.
- Haworth projections represent the cyclic structures of monosaccharides.
- Monosaccharides contain either an aldehyde group (aldose) or a ketone group (ketose) and several –OH groups.
- Straight chain forms of sugars cyclize in solution to form ring structures containing an ether linkage.
- Glycosidic bonds form between monosaccharides forming disaccharides and polysaccharides.
- Carbohydrates are used as energy sources and energy reserves.

Applications and skills:

- Deduction of the structural formulas of disaccharides and polysaccharides from given monosaccharides.
- Relationship of the properties and functions of monosaccharides and polysaccharides to their chemical structures.

International-mindedness:

- Sugar is a major international commodity and is produced in about 130 different countries. Approximately three-quarters of production comes from sugar cane in tropical and subtropical regions and the remainder comes from sugar beet which is cultivated in temperate climates.
- Diabetes is a chronic disease that occurs when the body cannot effectively regulate blood sugar, due to a failure in the production or functioning of insulin. The World Health Organization projects that deaths from diabetes will double between 2005 and 2030.
- Lactose intolerance is a condition in which the individual is not able to digest lactose, the sugar found in milk and dairy products. It is due to a failure to produce sufficient levels of lactase, the enzyme that hydrolyses lactose into glucose and galactose. Globally lactose intolerance is the norm. It is an example of a Western perspective invading science.

Theory of knowledge:

- The use of aspartame as an artificial sweetener has been controversial for many years as the side effects are not fully investigated. Should scientists be held morally responsible for the adverse consequences of their work?

B.4 Carbohydrates

Guidance:

- The straight chain and α-ring forms of glucose and fructose are given in the data booklet in section 34.
- The component monosaccharides of specific disaccharides and the linkage details of polysaccharides are not required.
- The distinction between α- and β- forms and the structure of cellulose are not required.

Utilization:

- Carbohydrates are used in the pharmaceutical industry to bind preparations into tablets.
- Ethanol is produced as a biofuel from the fermentation of carbohydrates in crops such as corn or sugar cane.

Syllabus and cross-curricular links:
Topics 10.1 and 10.2—organic functional groups
Topic 20.1—organic reactions
Topic 20.3—stereoisomerism
Option C.4—biofuels
Biology topic 2.3—carbohydrates

Aims:

- **Aim 6**: Experiments could include using Benedict’s or Fehling’s solution tests to distinguish between reducing sugars and non-reducing sugars or using iodine solution to test for the presence of starch.
- **Aim 8**: The production of biofuels from crops raises many questions about related issues such as deforestation, soil erosion and sustainability. The “food vs fuel” debate refers to the controversies arising from developments that divert agricultural crops into biofuel production.

Essential idea: Vitamins are organic micronutrients with diverse functions that must be obtained from the diet.

B.5 Vitamins

Nature of science:

Making observations and evaluating claims—the discovery of vitamins (*vital amines*) is an example of scientists seeking a cause for specific observations. This resulted in the explanation of deficiency diseases (eg scurvy and beriberi). (1.8)

Understandings:

- Vitamins are organic micronutrients which (mostly) cannot be synthesized by the body but must be obtained from suitable food sources.
- The solubility (water or fat) of a vitamin can be predicted from its structure.
- Most vitamins are sensitive to heat.
- Vitamin deficiencies in the diet cause particular diseases and affect millions of people worldwide.

Applications and skills:

- Comparison of the structures of vitamins A, C and D.
- Discussion of the causes and effects of vitamin deficiencies in different countries and suggestion of solutions.

Guidance:

- The structures of vitamins A, C and D are provided in the data booklet section 35.
- Specific food sources of vitamins or names of deficiency diseases do not have to be learned.

International-mindedness:

- The food supplements industry, especially the sale of vitamin pills, has become very lucrative in many countries.
- Vitamin D deficiency is increasing, partly as a result of greater protection of the skin from sunlight.

Theory of knowledge:

- What are the ethical considerations in adding supplements to commonly consumed foods, such as fluoride to water or iodine to salt? Public bodies can protect the individual but also limit their freedom. How do we know what is best for society and the individual?
- Linus Pauling is the only man to win two individual Nobel Prizes. His claim that vitamin C supplements could prevent diseases such as the common cold led to their widespread use. What is the role of authority in communicating scientific knowledge to the public?

Utilization:

Syllabus and cross-curricular links:
Topics 4.1, 4.2 and 4.3—structure and physical properties
Topic 10.1—organic functional groups
Topic 20.3—configurational isomerism
Biology option D.2—human nutrition and health

Aims:

- **Aim 6**: Experiments could include the DCPIP determination of vitamin C levels in foods.

Essential idea: Our increasing knowledge of biochemistry has led to several environmental problems, while also helping to solve others.

B.6 Biochemistry and the environment

Nature of science:

Risk assessment, collaboration, ethical considerations—it is the responsibility of scientists to consider the ways in which products of their research and findings negatively impact the environment, and to find ways to counter this. For example, the use of enzymes in biological detergents and to break up oil spills, and green chemistry in general. (4.8)

Understandings:

- Xenobiotics refer to chemicals that are found in an organism that are not normally present there.
- Biodegradable/compostable plastics can be consumed or broken down by bacteria or other living organisms.
- Host–guest chemistry involves the creation of synthetic host molecules that mimic some of the actions performed by enzymes in cells, by selectively binding to specific guest species, such as toxic materials in the environment.
- Enzymes have been developed to help in the breakdown of oil spills and other industrial wastes.
- Enzymes in biological detergents can improve energy efficiency by enabling effective cleaning at lower temperatures.
- Biomagnification is the increase in concentration of a substance in a food chain.
- Green chemistry, also called sustainable chemistry, is an approach to chemical research and engineering that seeks to minimize the production and release to the environment of hazardous substances.

Applications and skills:

- Discussion of the increasing problem of xenobiotics such as antibiotics in sewage treatment plants.
- Description of the role of starch in biodegradable plastics.

International-mindedness:

- The term green chemistry was first coined in 1991, and acceptance of its philosophy has led to developments in education and legislation in many countries.
- Use of the pesticide DDT is banned in most countries due to its toxic effects and biomagnification. Its use continues, however, in countries where malaria remains a major public health challenge.

Utilization:

Syllabus and cross-curricular links:
Topic 4.4—intermolecular forces
Topic 10.1—natural and synthetic organic compounds
Options A.5 and A.7—environmental impact of plastics
Option D.2—antibiotics

Aims:

- **Aim 6**: Experiments could include the comparison of the breakdown of biodegradable and non-biodegradable plastics in the environment.
- **Aim 6**: Risk assessment, including the risks to the environment, is an essential part of all experimental work.
- **Aim 8**: The development of the science of green chemistry has raised awareness of the environmental and ethical implications of using science and technology.

B.6 Biochemistry and the environment	
• Application of host–guest chemistry to the removal of a specific pollutant in the environment. • Description of an example of biomagnification, including the chemical source of the substance. Examples could include heavy metals or pesticides. • Discussion of the challenges and criteria in assessing the “greenness” of a substance used in biochemical research, including the atom economy. **Guidance:** • Specific names of “green chemicals” such as solvents are not expected. • The emphasis in explanations of host–guest chemistry should be on non-covalent bonding within the supramolecule.	

Additional higher level topics

Essential idea: Analyses of protein activity and concentration are key areas of biochemical research.

B.7 Proteins and enzymes	
Nature of science: Theories can be superseded—"lock and key" hypothesis to "induced fit" model for enzymes. (1.9) Collaboration and ethical considerations—scientists collaborate to synthesize new enzymes and to control desired reactions (ie waste control). (4.5)	
Understandings: • Inhibitors play an important role in regulating the activities of enzymes. • Amino acids and proteins can act as buffers in solution. • Protein assays commonly use UV-vis spectroscopy and a calibration curve based on known standards. **Applications and skills:** • Determination of the maximum rate of reaction (V_{max}) and the value of the Michaelis constant (K_m) for an enzyme by graphical means, and explanation of its significance. • Comparison of competitive and non-competitive inhibition of enzymes with reference to protein structure, the active site and allosteric site. • Explanation of the concept of product inhibition in metabolic pathways. • Calculation of the pH of buffer solutions, such as those used in protein analysis and in reactions involving amino acids in solution. • Determination of the concentration of a protein in solution from a calibration curve using the Beer–Lambert law.	**International-mindedness:** • Technologies based on enzyme activity go back to ancient times in many parts of the world. Brewing and cheese-making are often associated with particular place names. **Theory of knowledge:** • The term "lock-and-key" is an effective metaphor but the "induced fit" model is a better model. How are metaphors and models used in the construction of knowledge? **Utilization:** • Enzymes are widely used in industrial and domestic applications. Examples include biological detergents, textiles, foods and beverages, and biodegradable plastics. Advances in protein engineering have led to the synthesis of enzymes that are effective in a wide range of conditions. Syllabus and cross-curricular links: Topic 6.1—chemical kinetics Topics 8.1, 8.3 and 8.4—the pH scale and conjugate acids and bases Topics 18.2 and 18.3—acid–base calculations and pH curves

B.7 Proteins and enzymes	
Guidance: • The effects of competitive and non-competitive inhibitors on K_m and V_{max} values should be covered. • The Henderson–Hasselbalch equation is given in the data booklet in section 1. • For UV-vis spectroscopy, knowledge of particular reagents and wavelengths is not required.	**Aims:** • **Aim 6**: Experiments could include measuring enzyme activity with changing conditions of temperature, pH and heavy metal ion concentration. • **Aim 7**: Data-logging experiments with temperature or pH probes to investigate enzyme activity under different conditions; or computer modelling of enzyme–substrate interactions. • **Aim 8**: Many enzyme technologies help mitigate damaging environmental effects of chemicals, such as from leather, paper and oil industries.

Essential idea: DNA is the genetic material that expresses itself by controlling the synthesis of proteins by the cell.

B.8 Nucleic acids

Nature of science:

Scientific method—the discovery of the structure of DNA is a good example of different approaches to solving the same problem. Scientists used models and diffraction experiments to develop the structure of DNA. (1.3)

Developments in scientific research follow improvements in apparatus—double helix from X-ray diffraction provides explanation for known functions of DNA. (3.7)

Understandings:

- Nucleotides are the condensation products of a pentose sugar, phosphoric acid and a nitrogenous base—adenine (A), guanine (G), cytosine (C), thymine (T) or uracil (U).
- Polynucleotides form by condensation reactions.
- DNA is a double helix of two polynucleotide strands held together by hydrogen bonds.
- RNA is usually a single polynucleotide chain that contains uracil in place of thymine, and a sugar ribose in place of deoxyribose.
- The sequence of bases in DNA determines the primary structure of proteins synthesized by the cell using a triplet code, known as the genetic code, which is universal.
- Genetically modified organisms have genetic material that has been altered by genetic engineering techniques, involving transferring DNA between species.

Applications and skills:

- Explanation of the stability of DNA in terms of the interactions between its hydrophilic and hydrophobic components.
- Explanation of the origin of the negative charge on DNA and its association with basic proteins (histones) in chromosomes.
- Deduction of the nucleotide sequence in a complementary strand of DNA or a molecule of RNA from a given polynucleotide sequence.

International-mindedness:

- The Human Genome Project was an international research programme whose goal was to complete the mapping and sequencing of all the genes in the human genome.
- The policies on the labelling of genetically modified (GM) foods vary greatly in different countries.
- Most of the genetically modified organisms are protected by international patents. What effect does this have on the global economy and scientific community?

Theory of knowledge:

- DNA stores information but not knowledge.
- What are the differences between information and knowledge?
- The Nobel Prize in Physiology or Medicine 1962 was awarded jointly to Crick, Watson and Wilkins "for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material". What is the role of collaboration in advancing knowledge?
- The existence of DNA databases opens up questions of individual privacy and the extent to which government has the right of access to personal information. Who has the right to access knowledge of an individual’s DNA?

B.8 Nucleic acids	
• Explanation of how the complementary pairing between bases enables DNA to replicate itself exactly. • Discussion of the benefits and concerns of using genetically modified foods. **Guidance:** • Structures of the nitrogenous bases and ribose and deoxyribose sugars are given in the data booklet in section 34. • Knowledge of the different forms of RNA is not required. • Details of the process of DNA replication are not required. • Limit expression of DNA to the concept of a four-unit base code determining a twenty-unit amino acid sequence. Details of transcription and translation are not required.	**Utilization:** • Knowledge of DNA sequencing has transformed several aspects of legal enquiry, including forensics and paternity cases. It is also widely used in studies of ancestry and human migration. • DNA sequencing is an important aspect of the study of biochemical evolution. Syllabus and cross-curricular links: Topic 4.4—hydrogen bonding, intermolecular interactions Topic 8.1—acid–base interactions Biology topics 2.6 and 7.1—DNA and RNA structure **Aims:** • **Aim 5**: The story of the rivalry between the different teams involved in the elucidation of DNA structure in the 1950s is an example of a failure of effective collaboration and communication during scientific activities. • **Aim 6**: Experiments could include DNA extraction from cells and investigation of its physical properties, and model building exercises of DNA structure, including the specific base pairings between a purine and a pyrimidine. • **Aim 7**: Databases exist of genetic sequences from different organisms. • **Aim 8**: Many ethical questions are raised by our knowledge of the human genome, including cloning, genetic engineering, gene therapy, and so on.

Essential idea: Biological pigments include a variety of chemical structures with diverse functions which absorb specific wavelengths of light.

B.9 Biological pigments

Nature of science:

Use of data—quantitative measurements of absorbance are a reliable means of communicating data based on colour, which was previously subjective and difficult to replicate. (3.1)

Understandings:

- Biological pigments are coloured compounds produced by metabolism.
- The colour of pigments is due to highly conjugated systems with delocalized electrons, which have intense absorption bands in the visible region.
- Porphyrin compounds, such as hemoglobin, myoglobin, chlorophyll and many cytochromes are chelates of metals with large nitrogen-containing macrocyclic ligands.
- Hemoglobin and myoglobin contain heme groups with the porphyrin group bound to an iron(II) ion.
- Cytochromes contain heme groups in which the iron ion interconverts between iron(II) and iron(III) during redox reactions.
- Anthocyanins are aromatic, water-soluble pigments widely distributed in plants. Their specific colour depends on metal ions and pH.
- Carotenoids are lipid-soluble pigments, and are involved in harvesting light in photosynthesis. They are susceptible to oxidation, catalysed by light.

Applications and skills:

- Explanation of the sigmoidal shape of hemoglobin's oxygen dissociation curve in terms of the cooperative binding of hemoglobin to oxygen.
- Discussion of the factors that influence oxygen saturation of hemoglobin, including temperature, pH and carbon dioxide.
- Description of the greater affinity of oxygen for foetal hemoglobin.

International-mindedness:

- Artificial colours are commonly added during the commercial preparation and processing of food. The list of approved food colours varies greatly by country, which raises questions for international trade.

Theory of knowledge:

- Experiments show that our appreciation of food is based on an interaction between our senses. How do the different senses interact in giving us empirical knowledge about the world?

Utilization:

- Different tones of skin, eye and hair colour are the result of differences in the concentration of the pigment melanin.
- People whose ancestors have lived at high altitude for many generations have developed hemoglobin with a higher affinity for oxygen.
- The purplish-red colour of meat is largely due to the presence of myoglobin. The change in colour to brown on cooking occurs as the iron ion becomes oxidized to Fe^{3+}.
- Anthocyanins and carotenoids provide visible signals for plants to attract insects and birds for pollination and seed dispersal. They also protect plants from damage caused by UV light.

Syllabus and cross-curricular links:
Topic 8.2—indicators
Topic 13.2—complex ions
Option C.8—electronic conjugation and dye-sensitized solar cells

B.9 Biological pigments

- Explanation of the action of carbon monoxide as a competitive inhibitor of oxygen binding.
- Outline of the factors that affect the stabilities of anthocyanins, carotenoids and chlorophyll in relation to their structures.
- Explanation of the ability of anthocyanins to act as indicators based on their sensitivity to pH.
- Description of the function of photosynthetic pigments in trapping light energy during photosynthesis.
- Investigation of pigments through paper and thin layer chromatography.

Guidance:

- The structures of chlorophyll, heme B and specific examples of anthocyanins and carotenoids are given in the data booklet in section 35; details of other pigment names and structures are not required.
- Explanation of cooperative binding in hemoglobin should be limited to conformational changes occurring in one polypeptide when it becomes oxygenated.
- Knowledge of specific colour changes with changing conditions is not required.

Aims:

- **Aim 6**: Experiments could include the extraction and isolation of pigments from plant sources using solvents and separating funnel or the use of anthocyanins as pH indicators.
- **Aim 7**: Use of data loggers for collecting absorption data.

Essential idea: Most biochemical processes are stereospecific and involve only molecules with certain configuration of chiral carbon atoms.

B.10 Stereochemistry in biomolecules

Nature of science:

Theories used to explain natural phenomena/evaluate claims—biochemistry involves many chiral molecules with biological activity specific to one enantiomer. Chemical reactions in a chiral environment act as a guiding distinction between living and non-living matter. (2.2)

Understandings:

- With one exception, amino acids are chiral, and only the L-configuration is found in proteins.
- Naturally occurring unsaturated fat is mostly in the *cis* form, but food processing can convert it into the *trans* form.
- D and L stereoisomers of sugars refer to the configuration of the chiral carbon atom furthest from the aldehyde or ketone group, and D forms occur most frequently in nature.
- Ring forms of sugars have isomers, known as α and β, depending on whether the position of the hydroxyl group at carbon 1 (glucose) or carbon 2 (fructose) lies below the plane of the ring (α) or above the plane of the ring (β).
- Vision chemistry involves the light activated interconversion of *cis*- and *trans*-isomers of retinal.

Applications and skills:

- Description of the hydrogenation and partial hydrogenation of unsaturated fats, including the production of *trans*-fats, and a discussion of the advantages and disadvantages of these processes.
- Explanation of the structure and properties of cellulose, and comparison with starch.
- Discussion of the importance of cellulose as a structural material and in the diet.
- Outline of the role of vitamin A in vision, including the roles of opsin, rhodopsin

International-mindedness:

- Different countries have very different standards of food labelling with respect to its chemical content, including the type of fats present.

Utilization:

Syllabus and cross-curricular links:
Topic 10.1—organic functional groups
Topic 20.1—organic reactions
Topic 20.3—stereoisomerism
Option A.4—intermolecular/London forces

Aims:

- **Aim 8**: Ethical questions arise through the use of saturated and *trans*-fats, particularly in the fast-food industry.

B.10 Stereochemistry in biomolecules	
and *cis*- and *trans*-retinal. **Guidance:** • Names of the enzymes involved in the visual cycle are not required. • Relative melting points of saturated and *cis*-/*trans*-unsaturated fats should be covered.	

Core topics

Essential idea: Societies are completely dependent on energy resources. The quantity of energy is conserved in any conversion but the quality is degraded.

C.1 Energy sources

Nature of science:

Use theories to explain natural phenomena—energy changes in the world around us result from potential and kinetic energy changes at the molecular level.

Energy has both quantity and quality. (2.2)

Understandings:

- A useful energy source releases energy at a reasonable rate and produces minimal pollution.
- The quality of energy is degraded as heat is transferred to the surroundings. Energy and materials go from a concentrated into a dispersed form. The quantity of the energy available for doing work decreases.
- Renewable energy sources are naturally replenished. Non-renewable energy sources are finite.
- $\text{Energy density} = \frac{\text{energy released from fuel}}{\text{volume of fuel consumed}}$.
- $\text{Specific energy} = \frac{\text{energy released from fuel}}{\text{mass of fuel consumed}}$.
- $\text{The effeciency of an energy transfer} = \frac{\text{useful output energy}}{\text{total input energy}} \times 100\%$.

Applications and skills:

- Discussion of the use of different sources of renewable and non-renewable energy.
- Determination of the energy density and specific energy of a fuel from the enthalpies of combustion, densities and the molar mass of fuel.
- Discussion of how the choice of fuel is influenced by its energy density or specific energy.

International-mindedness:

- The International Energy Agency is an autonomous organization based in Paris which works to ensure reliable, affordable and clean energy for its 28 member countries and beyond.
- The International Renewable Energy Agency (IRENA), based in Abu Dhabi, UAE, was founded in 2009 to promote increased adoption and sustainable use of renewable energy sources (bioenergy, geothermal energy, hydropower, ocean, solar and wind energy).

Theory of knowledge:

- “I have no doubt that we will be successful in harnessing the sun’s energy. If sunbeams were weapons of war we would have had solar energy centuries ago.” (Lord George Porter). In what ways might social, political, cultural and religious factors affect the types of research that are financed and undertaken, or rejected?
- There are many ethical issues raised by energy generation and its consequent contributions to pollution and climate change.What is the influence of political pressure on different areas of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 5.1—enthalpies of combustion
Topic 10.2—the combustion of hydrocarbons
Environmental systems and societies topics—3.2, 3.3, 3.5 and 3.6
Physics topic 8.1—energy density

C.1 Energy sources	
• Determination of the efficiency of an energy transfer process from appropriate data. • Discussion of the advantages and disadvantages of the different energy sources in C.2 through to C.8.	**Aims:** • **Aim 1**: Discussions of the possible energy sources provide opportunities for scientific study and creativity within a global context. • **Aim 6**: The energy density of different fuels could be investigated experimentally. • **Aim 7**: Databases of energy statistics on a global and national scale can be explored here. • **Aim 8**: Energy production has global economic and environmental dimensions. The choices made in this area have moral and ethical implications.

Essential idea: The energy of fossil fuels originates from solar energy which has been stored by chemical processes over time. These abundant resources are non-renewable but provide large amounts of energy due to the nature of chemical bonds in hydrocarbons.

C.2 Fossil fuels

Nature of science:

Scientific community and collaboration—the use of fossil fuels has had a key role in the development of science and technology. (4.1)

Understandings:

- Fossil fuels were formed by the reduction of biological compounds that contain carbon, hydrogen, nitrogen, sulfur and oxygen.
- Petroleum is a complex mixture of hydrocarbons that can be split into different component parts called fractions by fractional distillation.
- Crude oil needs to be refined before use. The different fractions are separated by a physical process in fractional distillation.
- The tendency of a fuel to auto-ignite, which leads to "knocking" in a car engine, is related to molecular structure and measured by the octane number.
- The performance of hydrocarbons as fuels is improved by the cracking and catalytic reforming reactions.
- Coal gasification and liquefaction are chemical processes that convert coal to gaseous and liquid hydrocarbons.
- A carbon footprint is the total amount of greenhouse gases produced during human activities. It is generally expressed in equivalent tons of carbon dioxide.

Applications and skills:

- Discussion of the effect of chain length and chain branching on the octane number.
- Discussion of the reforming and cracking reactions of hydrocarbons and explanation how these processes improve the octane number.
- Deduction of equations for cracking and reforming reactions, coal gasification and liquefaction.

International-mindedness:

- The choice of fossil fuel used by different countries depends on availability, and economic, societal, environmental and technological factors.
- Different fuel rating systems (RON, MON or PON) are used in different countries.
- Ocean drilling, oil pipelines and oil spills are issues that demand international cooperation and agreement.

Utilization:

Syllabus and cross-curricular links:
Topics 5.1 and 5.3—enthalpy changes of combustion
Topics 10.1 and 20.3—hydrocarbons and isomerism
Topic 10.2 and option C.5—global warming
Option C.8—solar cells
Biology topic 4.3—carbon cycling

Aims:

- **Aim 6**: Possible experiments include fractional distillation and catalytic cracking reactions.
- **Aim 7**: Databases of energy statistics on a global and national scale can be explored here.
- **Aim 7**: Many online calculators are available to calculate carbon footprints.
- **Aim 8**: Consideration of the advantages and disadvantages of fossil fuels illustrates the economic and environmental implications of using science and technology.

C.2 Fossil fuels	
• Discussion of the advantages and disadvantages of the different fossil fuels. • Identification of the various fractions of petroleum, their relative volatility and their uses. • Calculations of the carbon dioxide added to the atmosphere, when different fuels burn and determination of carbon footprints for different activities. **Guidance:** • The cost of production and availability (reserves) of fossil fuels and their impact on the environment should be considered.	

Essential idea: The fusion of hydrogen nuclei in the sun is the source of much of the energy needed for life on Earth. There are many technological challenges in replicating this process on Earth but it would offer a rich source of energy. Fission involves the splitting of a large unstable nucleus into smaller stable nuclei.

C.3 Nuclear fusion and fission

Nature of science:

Assessing the ethics of scientific research—widespread use of nuclear fission for energy production would lead to a reduction in greenhouse gas emissions. Nuclear fission is the process taking place in the atomic bomb and nuclear fusion that in the hydrogen bomb. (4.5)

Understandings:

Nuclear fusion

- Light nuclei can undergo fusion reactions as this increases the binding energy per nucleon.
- Fusion reactions are a promising energy source as the fuel is inexpensive and abundant, and no radioactive waste is produced.
- Absorption spectra are used to analyse the composition of stars.

Nuclear fission

- Heavy nuclei can undergo fission reactions as this increases the binding energy per nucleon.
- ^{235}U undergoes a fission chain reaction:
  $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow$ X + Y + neutrons.
- The critical mass is the mass of fuel needed for the reaction to be self-sustaining.
- ^{239}Pu, used as a fuel in “breeder reactors”, is produced from ^{238}U by neutron capture.
- Radioactive waste may contain isotopes with long and short half-lives.
- Half-life is the time it takes for half the number of atoms to decay.

International-mindedness:

- The use of nuclear energy is monitored internationally by the International Atomic Energy Agency.
- High-energy particle physics research involves international collaboration. There are accelerator facilities at CERN, DESY, SLAC, Fermi lab and Brookhaven. Results are disseminated and shared by scientists in many countries.
- The ITER project is a collaboration between many countries and aims to demonstrate that fusion is an energy source of the future.

Theory of knowledge:

- The use of nuclear energy carries risks as well as benefits. Who should ultimately be responsible for assessing these? How do we know what is best for society and the individual?

Utilization:

Syllabus and cross-curricular links:
Topic 2.1—isotopes
Topic 2.2—the emission spectrum of hydrogen
Physics topic 7.2—nuclear fusion

Aims:

- **Aim 7**: Computer animations and simulations of radioactive decay, and nuclear fusion and fission reactions.
- **Aim 8**: Consideration of the environmental impact of nuclear energy illustrating

C.3 Nuclear fusion and fission	
Applications and skills: *Nuclear fusion* • Construction of nuclear equations for fusion reactions. • Explanation of fusion reactions in terms of binding energy per nucleon. • Explanation of the atomic absorption spectra of hydrogen and helium, including the relationships between the lines and electron transitions. *Nuclear fission* • Deduction of nuclear equations for fission reactions. • Explanation of fission reactions in terms of binding energy per nucleon. • Discussion of the storage and disposal of nuclear waste. • Solution of radioactive decay problems involving integral numbers of half-lives. **Guidance:** • Students are not expected to recall specific fission reactions. • The workings of a nuclear power plant are not required. • Safety and risk issues include: health, problems associated with nuclear waste and core meltdown, and the possibility that nuclear fuels may be used in nuclear weapons. • The equations, $N = N_0 e^{-\lambda t}$ and $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ are given in section 1 of the data booklet.	the implications of using science and technology.

Essential idea: Visible light can be absorbed by molecules that have a conjugated structure with an extended system of alternating single and multiple bonds. Solar energy can be converted to chemical energy in photosynthesis.

<table>
<tr><td colspan="2">C.4 Solar energy</td></tr>
<tr><td colspan="2">Nature of science:

Public understanding—harnessing the sun’s energy is a current area of research and challenges still remain. However, consumers and energy companies are being encouraged to make use of solar energy as an alternative energy source. (5.2)</td></tr>
<tr><td>Understandings:

• Light can be absorbed by chlorophyll and other pigments with a conjugated electronic structure.

• Photosynthesis converts light energy into chemical energy:
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

• Fermentation of glucose produces ethanol which can be used as a biofuel:
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

• Energy content of vegetable oils is similar to that of diesel fuel but they are not used in internal combustion engines as they are too viscous.

• Transesterification between an ester and an alcohol with a strong acid or base catalyst produces a different ester:
$RCOOR^1 + R^2OH \rightarrow RCOOR^2 + R^1OH$

• In the transesterification process, involving a reaction with an alcohol in the presence of a strong acid or base, the triglyceride vegetable oils are converted to a mixture mainly comprising of alkyl esters and glycerol, but with some fatty acids.

• Transesterification with ethanol or methanol produces oils with lower viscosity that can be used in diesel engines.

Applications and skills:

• Identification of features of the molecules that allow them to absorb visible light.</td>
<td>Theory of knowledge:

• The claims of “cold fusion” were dismissed as the results are not reproducible. Is it always possible to obtain replicable results in the natural sciences? Are reproducible results possible in other areas of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 5.3—bond enthalpies
Topic 20.1—mechanism of nuclear substitution reactions
Biology topic 2.9—photosynthesis

Aims:

• Aim 2: The conversion of solar energy is important in a number of different technologies.

• Aim 6: Experiments could include those involving photosynthesis, fermentation and transesterification.

• Aim 8: Transesterification reactions, with waste cooking oil, could reduce waste and produce excellent biofuels.</td></tr>
</table>

C.4 Solar energy	
• Explanation of the reduced viscosity of esters produced with methanol and ethanol. • Evaluation of the advantages and disadvantages of the use of biofuels. • Deduction of equations for transesterification reactions. **Guidance:** • Only a conjugated system with alternating double bonds needs to be covered.	

Essential idea: Gases in the atmosphere that are produced by human activities are changing the climate as they are upsetting the balance between radiation entering and leaving the atmosphere.

C.5 Environmental impact—global warming

Nature of science:

Transdisciplinary—the study of global warming encompasses a broad range of concepts and ideas and is transdisciplinary. (4.1)

Collaboration and significance of science explanations to the public—reports of the Intergovernmental Panel on Climate Change (IPCC). (5.2)

Correlation and cause and understanding of science—CO_2 levels and Earth average temperature show clear correlation but wide variations in the surface temperature of the Earth have occurred frequently in the past. (2.8)

Understandings:

- Greenhouse gases allow the passage of incoming solar short wavelength radiation but absorb the longer wavelength radiation from the Earth. Some of the absorbed radiation is re-radiated back to Earth.
- There is a heterogeneous equilibrium between concentration of atmospheric carbon dioxide and aqueous carbon dioxide in the oceans.
- Greenhouse gases absorb IR radiation as there is a change in dipole moment as the bonds in the molecule stretch and bend.
- Particulates such as smoke and dust cause global dimming as they reflect sunlight, as do clouds.

Applications and skills:

- Explanation of the molecular mechanisms by which greenhouse gases absorb infrared radiation.
- Discussion of the evidence for the relationship between the increased concentration of gases and global warming.
- Discussion of the sources, relative abundance and effects of different greenhouse gases.
- Discussion of the different approaches to the control of carbon dioxide emissions.

International-mindedness:

- This issue involves the international community working together to research and reduce the effects of global warming. Such attempts include the Intergovernmental Panel on Climate Change (IPCC) and the Kyoto Protocol which was extended in Qatar.

Theory of knowledge:

- Some people question the reality of climate change, and question the motives of scientists who have “exaggerated” the problem. How do we assess the evidence collected and the models used to predict the impact of human activities?

Utilization:

Syllabus and cross-curricular links:
Topics 7.1 and 17.1—equilibrium systems
Topic 8.2—acid–base equilibria
Topic 11.3—infrared spectra
Topic 13.2—transition metal complexes
Biology topic 4.4—climate change
Physics topic 8.1—thermal energy transfer

Aims:

- **Aim 6**: The equilibrium between aqueous and gaseous carbon dioxide could be experimentally investigated.

C.5 Environmental impact—global warming	
• Discussion of pH changes in the ocean due to increased concentration of carbon dioxide in the atmosphere. **Guidance:** • Greenhouse gases to be considered are CH_4, H_2O and CO_2.	• **Aim 7**: Computer modelling is a powerful tool by which knowledge can be gained about the greenhouse effect. • **Aim 8**: Discussions of climate change and green chemistry raise awareness of the ethical, economic and environmental implications of using science and technology.

Additional higher level topics

Essential idea: Chemical energy from redox reactions can be used as a portable source of electrical energy.

C.6 Electrochemistry, rechargeable batteries and fuel cells	
Nature of science: Environmental problems—redox reactions can be used as a source of electricity but disposal of batteries has environmental consequences. (4.8)	
Understandings: • An electrochemical cell has internal resistance due to the finite time it takes for ions to diffuse. The maximum current of a cell is limited by its internal resistance. • The voltage of a battery depends primarily on the nature of the materials used while the total work that can be obtained from it depends on their quantity. • In a primary cell the electrochemical reaction is not reversible. Rechargeable cells involve redox reactions that can be reversed using electricity. • A fuel cell can be used to convert chemical energy, contained in a fuel that is consumed, directly to electrical energy. • Microbial fuel cells (MFCs) are a possible sustainable energy source using different carbohydrates or substrates present in waste waters as the fuel. • The Nernst equation, $E = E^0 - \left(\frac{RT}{nF}\right) \ln Q$, can be used to calculate the potential of a half-cell in an electrochemical cell, under non-standard conditions. • The electrodes in a concentration cell are the same but the concentration of the electrolyte solutions at the cathode and anode are different. **Applications and skills:** • Distinction between fuel cells and primary cells. • Deduction of half equations for the electrode reactions in a fuel cell.	**International-mindedness:** • Are battery recycling programmes equivalent in different areas of the globe? **Theory of knowledge:** • Does scientific language and vocabulary have primarily a descriptive or an interpretative function? Are the terms “electric current” and “internal resistance” accurate descriptions of reality or metaphors? **Utilization:** Syllabus and cross-curricular links: Topic 9.1—redox reactions Topic 19.1—electrochemical cells Biology topic 6.5—muscle and nerve cells discussed in biology are concentration cells Physics topic 5.3—the relationship between electrical power, voltage, resistance and current **Aims:** • **Aim 2**: The conversion of chemical energy to electricity is important in a number of different technologies. • **Aim 6**: The factors that affect the voltage of a cell and the lead–acid battery could be investigated experimentally.

C.6 Electrochemistry, rechargeable batteries and fuel cells	
• Comparison between fuel cells and rechargeable batteries. • Discussion of the advantages of different types of cells in terms of size, mass and voltage. • Solution of problems using the Nernst equation. • Calculation of the thermodynamic efficiency ($\Delta G/\Delta H$) of a fuel cell. • Explanation of the workings of rechargeable and fuel cells including diagrams and relevant half-equations. **Guidance:** • A battery should be considered as a portable electrochemical source made up of one or more voltaic (galvanic) cells connected in series. • The Nernst equation is given in the data booklet in section 1. • Hydrogen and methanol should be considered as fuels for fuel cells. The operation of the cells under acid and alkaline conditions should be considered. Students should be familiar with proton-exchange membrane (PEM) fuel cells. • The *Geobacter* species of bacteria, for example, can be used in some cells to oxidize the ethanoate ions (CH_3COO^-) under anaerobic conditions. • The lead–acid storage battery, the nickel–cadmium (NiCad) battery and the lithium–ion battery should be considered. • Students should be familiar with the anode and cathode half-equations and uses of the different cells.	• **Aim 8**: Consideration of the advantages and disadvantages of the different energy sources shows the economic and environmental implications of using science and technology. The environmental aspects of fuel cells, especially with regard to methanol, could be discussed. • **Aim 8**: Disposal of primary batteries and the chemicals they use can introduce land and water pollution problems. Appreciation of the environmental impact of cadmium and lead pollution. • **Aim 8**: Bacterial fuel cells use substrates found in waste water as the fuel and so can be used to clean up the environment.

Essential idea: Large quantities of energy can be obtained from small quantities of matter.

C.7 Nuclear fusion and nuclear fission

Nature of science:

Trends and discrepancies—our understanding of nuclear processes came from both theoretical and experimental advances. Intermolecular forces in UF_6 are anomalous and do not follow the normal trends. (3.1)

Understandings:

Nuclear fusion:

- The mass defect (Δm) is the difference between the mass of the nucleus and the sum of the masses of its individual nucleons.
- The nuclear binding energy (ΔE) is the energy required to separate a nucleus into protons and neutrons.

Nuclear fission:

- The energy produced in a fission reaction can be calculated from the mass difference between the products and reactants using the Einstein mass–energy equivalence relationship $E = mc^2$.
- The different isotopes of uranium in uranium hexafluoride can be separated, using diffusion or centrifugation causing fuel enrichment.
- The effusion rate of a gas is inversely proportional to the square root of the molar mass (Graham's Law).
- Radioactive decay is kinetically a first order process with the half-life related to the decay constant by the equation $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$.
- The dangers of nuclear energy are due to the ionizing nature of the radiation it produces which leads to the production of oxygen free radicals such as superoxide (O_2^-), and hydroxyl ($HO^\cdot$). These free radicals can initiate chain reactions that can damage DNA and enzymes in living cells.

International-mindedness:

- There are only a very small number of countries that have developed nuclear weapons and the International Atomic Energy Agency strives to limit the spread of this technology. There are disputes about whether some countries are developing nuclear energy for peaceful or non-peaceful purposes.
- Nuclear incidents have a global effect; the accidents at Three Mile Island and Chernobyl and the problems at Fukushima caused by a tsunami could be discussed to illustrate the potential dangers.

Theory of knowledge:

- "There is no likelihood that humans will ever tap the power of the atom." (Robert Millikan, Nobel Laureate Physics 1923 quoted in 1928). How can the impact of new technologies be predicted? How reliable are these predictions? How important are the opinions of experts in the search for knowledge?
- The release of energy during fission reactions can be used in times of peace to generate energy, but also can lead to destruction in time of war. Should scientists be held morally responsible for the applications of their discoveries? Is there any area of scientific knowledge the pursuit of which is morally unacceptable?

Utilization:

Syllabus and cross-curricular links:
Topics 4.1 and 4.3—structure and bonding
Topic 16.1—first order reactions
Physics topic 7.2—nuclear fusion
Geography—the different polices and attitudes to nuclear energy are discussed in resources sections in the guide

C.7 Nuclear fusion and nuclear fission	
Applications and skills: *Nuclear fusion:* • Calculation of the mass defect and binding energy of a nucleus. • Application of the Einstein mass–energy equivalence relationship, $E = mc^2$, to determine the energy produced in a fusion reaction. *Nuclear fission:* • Application of the Einstein mass–energy equivalence relationship to determine the energy produced in a fission reaction. • Discussion of the different properties of UO_2 and UF_6 in terms of bonding and structure. • Solution of problems involving radioactive half-life. • Explanation of the relationship between Graham's law of effusion and the kinetic theory. • Solution of problems on the relative rate of effusion using Graham's law. **Guidance:** • Students are not expected to recall specific fission reactions. • The workings of a nuclear power plant are not required. • Safety and risk issues include: health, problems associated with nuclear waste, and the possibility that nuclear fuels may be used in nuclear weapons. • Graham's law of effusion is given in the data booklet in section 1. • Decay relationships are given in the data booklet in section 1. • A binding energy curve is given in the data booklet in section 36.	**Aims**: • **Aim 7**: Computer animations and simulations of radioactive decay, and nuclear fusion and fission reactions. • **Aim 8**: Consideration of the advantages and disadvantages of nuclear fusion illustrates the economic and environmental implications of using science and technology. The use of fusion reactions in the hydrogen bomb can also be discussed.

Essential idea: When solar energy is converted to electrical energy the light must be absorbed and charges must be separated. In a photovoltaic cell both of these processes occur in the silicon semiconductor, whereas these processes occur in separate locations in a dye-sensitized solar cell (DSSC).

C.8 Photovoltaic cells and dye-sensitized solar cells (DSSC)

Nature of science:

Transdisciplinary—a dye-sensitized solar cell, whose operation mimics photosynthesis and makes use of TiO_2 nanoparticles, illustrates the transdisciplinary nature of science and the link between chemistry and biology. (4.1)

Funding—the level of funding and the source of the funding is crucial in decisions regarding the type of research to be conducted. The first voltaic cells were produced by NASA for space probes and were only later used on Earth. (4.7)

Understandings:

- Molecules with longer conjugated systems absorb light of longer wavelength.
- The electrical conductivity of a semiconductor increases with an increase in temperature whereas the conductivity of metals decreases.
- The conductivity of silicon can be increased by doping to produce n-type and p-type semiconductors.
- Solar energy can be converted to electricity in a photovoltaic cell.
- DSSCs imitate the way in which plants harness solar energy. Electrons are "injected" from an excited molecule directly into the TiO_2 semiconductor.
- The use of nanoparticles coated with light-absorbing dye increases the effective surface area and allows more light over a wider range of the visible spectrum to be absorbed.

Applications and skills:

- Relation between the degree of conjugation in the molecular structure and the wavelength of the light absorbed.
- Explanation of the operation of the photovoltaic and dye-sensitized solar cell.
- Explanation of how nanoparticles increase the efficiency of DSSCs.
- Discussion of the advantages of the DSSC compared to the silicon-based

International-mindedness:

- The harnessing of solar energy could change the economic fortunes of countries with good supplies of sunlight and unused land.

Theory of knowledge:

- A conjugated system has some similarities with a violin string. How useful is this metaphor? What are the underlying reasons for these similarities? What role do models and metaphors play in the acquisition of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 3.2—patterns in ionization energy
Topic 9.1—redox reactions
Biology topic 2.9—photosynthesis

Aims:

- **Aim 6**: Students could build an inexpensive dye-sensitized solar cell and investigate their photovoltaic properties.
- **Aim 7**: The properties of DSSCs can be best investigated using data loggers.

C.8 Photovoltaic cells and dye-sensitized solar cells (DSSC)	
photovoltaic cell. **Guidance:** • The relative conductivity of metals and semiconductors should be related to ionization energies. • Only a simple treatment of the operation of the cells is needed. In p-type semiconductors, electron holes in the crystal are created by introducing a small percentage of a group 3 element. In n-type semiconductors inclusion of a group 5 element provides extra electrons. • In a photovoltaic cell the light is absorbed and the charges separated in the silicon semiconductor. The processes of absorption and charge separation are separated in a dye-sensitized solar cell. • Specific redox and electrode reactions in the newer Grätzel DSSC should be covered. An example is the reduction of I_2/I_3^- ions to I^-.	

Core topics

Essential idea: Medicines and drugs have a variety of different effects on the functioning of the body.

D.1 Pharmaceutical products and drug action	
Nature of science: Risks and benefits—medicines and drugs go through a variety of tests to determine their effectiveness and safety before they are made commercially available. Pharmaceutical products are classified for their use and abuse potential. (4.8)	
Understandings: • In animal studies, the therapeutic index is the lethal dose of a drug for 50% of the population (*LD50*) divided by the minimum effective dose for 50% of the population (*ED50*). • In humans, the therapeutic index is the toxic dose of a drug for 50% of the population (*TD50*) divided by the minimum effective dose for 50% of the population (*ED50*). • The therapeutic window is the range of dosages between the minimum amounts of the drug that produce the desired effect and a medically unacceptable adverse effect. • Dosage, tolerance, addiction and side effects are considerations of drug administration. • Bioavailability is the fraction of the administered dosage that reaches the target part of the human body. • The main steps in the development of synthetic drugs include identifying the need and structure, synthesis, yield and extraction. • Drug–receptor interactions are based on the structure of the drug and the site of activity.	**International-mindedness:** • In some countries certain drugs are only available with prescription while in other countries these same drugs are available over the counter. **Theory of knowledge:** • The same drug can be identified by different names. Are names simply labels or do they influence our other ways of knowing? • Drugs trials use double blind tests. When is it ethically acceptable to deceive people? • All drugs carry risks as well as benefits. Who should ultimately be responsible for assessing these? Public bodies can protect the individual but also limit their freedom. How do we know what is best for society and the individual? **Aims:** • **Aim 9**: There have been advances in the development of pharmaceuticals, but there are many limitations to their impact and reach. • **Aim 10**: The development of new medicines is often done in collaboration with biologists and physicists.

D.1 Pharmaceutical products and drug action	
Applications and skills: • Discussion of experimental foundations for therapeutic index and therapeutic window through both animal and human studies. • Discussion of drug administration methods. • Comparison of how functional groups, polarity and medicinal administration can affect bioavailability. **Guidance:** • For ethical and economic reasons, animal and human tests of drugs (for LD_{50}/ED_{50} and TD_{50}/ED_{50} respectively) should be kept to a minimum.	

Essential idea: Natural products with useful medicinal properties can be chemically altered to produce more potent or safer medicines.

D.2 Aspirin and penicillin

Nature of science:

Serendipity and scientific discovery—the discovery of penicillin by Sir Alexander Fleming. (1.4)

Making observations and replication of data—many drugs need to be isolated, identified and modified from natural sources. For example, salicylic acid from bark of willow tree for relief of pain and fever. (1.8)

Understandings:

Aspirin:

- Mild analgesics function by intercepting the pain stimulus at the source, often by interfering with the production of substances that cause pain, swelling or fever.
- Aspirin is prepared from salicylic acid.
- Aspirin can be used as an anticoagulant, in prevention of the recurrence of heart attacks and strokes and as a prophylactic.

Penicillin:

- Penicillins are antibiotics produced by fungi.
- A beta-lactam ring is a part of the core structure of penicillins.
- Some antibiotics work by preventing cross-linking of the bacterial cell walls.
- Modifying the side-chain results in penicillins that are more resistant to the penicillinase enzyme.

International-mindedness:

- Aspirin is used in many different ways across the globe.
- The first antibacterial changed the way that disease was treated across the globe.

Theory of knowledge:

- Different painkillers act in different ways. How do we perceive pain, and how are our perceptions influenced by the other ways of knowing?
- "Chance favours only the prepared mind." (Louis Pasteur). Fleming's discovery of penicillin is often described as serendipitous but the significance of his observations would have been missed by non-experts. What influence does an open-minded attitude have on our perceptions?

Utilization:

Syllabus and cross-curricular links:
Topic 1.3—yield of reaction
Topic 10.2—functional groups
Biology topic 6.3—defence against infectious disease

D.2 Aspirin and penicillin	
Applications and skills: *Aspirin* • Description of the use of salicylic acid and its derivatives as mild analgesics. • Explanation of the synthesis of aspirin from salicylic acid, including yield, purity by recrystallization and characterization using IR and melting point. • Discussion of the synergistic effects of aspirin with alcohol. • Discussion of how the aspirin can be chemically modified into a salt to increase its aqueous solubility and how this facilitates its bioavailability. *Penicillin* • Discussion of the effects of chemically modifying the side-chain of penicillins. • Discussion of the importance of patient compliance and the effects of the over-prescription of penicillin. • Explanation of the importance of the beta-lactam ring on the action of penicillin. **Guidance:** • Students should be aware of the ability of acidic (carboxylic) and basic (amino) groups to form ionic salts, for example soluble aspirin. • Structures of aspirin and penicillin are available in the data booklet in section 37.	**Aims:** • **Aim 6**: Experiments could include the synthesis of aspirin. • **Aim 8**: Discuss the use/overuse of antibiotics for animals.

Essential idea: Potent medical drugs prepared by chemical modification of natural products can be addictive and become substances of abuse.

D.3 Opiates

Nature of science:

Data and its subsequent relationships—opium and its many derivatives have been used as a painkiller in a variety of forms for thousands of years. One of these derivatives is diamorphine. (3.1)

Understandings:

- The ability of a drug to cross the blood–brain barrier depends on its chemical structure and solubility in water and lipids.
- Opiates are natural narcotic analgesics that are derived from the opium poppy.
- Morphine and codeine are used as strong analgesics. Strong analgesics work by temporarily bonding to receptor sites in the brain, preventing the transmission of pain impulses without depressing the central nervous system.
- Medical use and addictive properties of opiate compounds are related to the presence of opioid receptors in the brain.

Applications and skills:

- Explanation of the synthesis of codeine and diamorphine from morphine.
- Description and explanation of the use of strong analgesics.
- Comparison of the structures of morphine, codeine and diamorphine (heroin).
- Discussion of the advantages and disadvantages of using morphine and its derivatives as strong analgesics.
- Discussion of side effects and addiction to opiate compounds.
- Explanation of the increased potency of diamorphine compared to morphine based on their chemical structure and solubility.

Guidance:

- Structures of morphine, codeine and diamorphine can be found in the data booklet in section 37.

International-mindedness:

- Many illegal drugs are cultivated or produced in a small number of countries and then sold and distributed globally. Cultural and economic viewpoints differ on the production and sale of opiates around the world.

Theory of knowledge:

- Cultures often clash over different perspectives and ideas. Is there any knowledge which is independent of culture?

Utilization:

Syllabus and cross-curricular links:
Topic 10.2—functional groups

Aims:

- **Aim 7**: Use computer animations for the investigation of 3-D visualizations of drugs and receptor sites.

Essential idea: Excess stomach acid is a common problem that can be alleviated by compounds that increase the stomach pH by neutralizing or reducing its secretion.

D.4 pH regulation of the stomach

Nature of science:

Collecting data through sampling and trialling—one of the symptoms of dyspepsia is the overproduction of stomach acid. Medical treatment of this condition often includes the prescription of antacids to instantly neutralize the acid, or H_2-receptor antagonists or proton pump inhibitors which prevent the production of stomach acid. (2.8)

Understandings:

- Non-specific reactions, such as the use of antacids, are those that work to reduce the excess stomach acid.
- Active metabolites are the active forms of a drug after it has been processed by the body.

Applications and skills:

- Explanation of how excess acidity in the stomach can be reduced by the use of different bases.
- Construction and balancing of equations for neutralization reactions and the stoichiometric application of these equations.
- Solving buffer problems using the Henderson–Hasselbalch equation.
- Explanation of how compounds such as ranitidine (Zantac) can be used to inhibit stomach acid production.
- Explanation of how compounds like omeprazole (Prilosec) and esomeprazole (Nexium) can be used to suppress acid secretion in the stomach.

Guidance:

- Antacid compounds should include calcium hydroxide, magnesium hydroxide, aluminium hydroxide, sodium carbonate and sodium bicarbonate.
- Structures for ranitidine and esomeprazole can be found in the data booklet in section 37.

International-mindedness:

- Different cultures (ie diet, lifestyle, etc) and genetics can affect the need for pH regulation of the stomach.

Theory of knowledge:

- Sometimes we utilize different approaches to solve the same problem. How do we decide between competing evidence and approaches?

Utilization:

Syllabus and cross-curricular links:
Topic 1.3—calculations involving solutions
Topics 8.2 and 8.4—neutralization
Topic 10.2—functional groups
Topic 20.3—enantiomers
Option B.7—amino acid buffers
Biology option D.1—digestion

Aims:

- **Aim 6**: Experiments could include titrations to test the effectiveness of various antacids.

Essential idea: Antiviral medications have recently been developed for some viral infections while others are still being researched.

D.5 Antiviral medications	
Nature of science: Scientific collaboration—recent research in the scientific community has improved our understanding of how viruses invade our systems. (4.1)	
Understandings: • Viruses lack a cell structure and so are more difficult to target with drugs than bacteria. • Antiviral drugs may work by altering the cell's genetic material so that the virus cannot use it to multiply. Alternatively, they may prevent the viruses from multiplying by blocking enzyme activity within the host cell. **Applications and skills:** • Explanation of the different ways in which antiviral medications work. • Description of how viruses differ from bacteria. • Explanation of how oseltamivir (Tamiflu) and zanamivir (Relenza) work as a preventative agent against flu viruses. • Comparison of the structures of oseltamivir and zanamivir. • Discussion of the difficulties associated with solving the AIDS problem. **Guidance:** • Structures for oseltamivir and zanamivir can be found in the data booklet in section 37.	**International-mindedness:** • How has the AIDS epidemic changed since its discovery in the early 1980s? What is needed to stop the spread of the disease? What is the global impact of this disease? **Utilization:** Syllabus and cross-curricular links: Options B.2 and B.7—proteins and enzymes Biology topic 11.1—vaccination **Aims:** • **Aim 8**: The control and treatment of HIV is exacerbated by the high price of anti-retroviral agents and sociocultural issues.

Essential idea: The synthesis, isolation, and administration of medications can have an effect on the environment.

D.6 Environmental impact of some medications	
Nature of science: Ethical implications and risks and problems—the scientific community must consider both the side effects of medications on the patient and the side effects of the development, production and use of medications on the environment (ie disposal of nuclear waste, solvents and antibiotic waste). (4.8)	
Understandings: • High-level waste (HLW) is waste that gives off large amounts of ionizing radiation for a long time. • Low-level waste (LLW) is waste that gives off small amounts of ionizing radiation for a short time. • Antibiotic resistance occurs when micro-organisms become resistant to antibacterials. **Applications and skills:** • Describe the environmental impact of medical nuclear waste disposal. • Discussion of environmental issues related to left-over solvents. • Explanation of the dangers of antibiotic waste, from improper drug disposal and animal waste, and the development of antibiotic resistance. • Discussion of the basics of green chemistry (sustainable chemistry) processes. • Explanation of how green chemistry was used to develop the precursor for Tamiflu (oseltamivir). **Guidance:** • The structure of oseltamivir is provided in the data booklet in section 37.	**International-mindedness:** • Consider how pharmaceutical companies determine how to spend research funds to develop new medications. • Do pharmaceutical companies have a responsibility to do research on rare diseases that will not provide them with significant financial profit? • Production of a drug typically involves a number of different organic reactions. What are the ethics governing the design (synthesis) of drugs? Do standards and practices vary by country and region? **Theory of knowledge:** • How do we balance ethical concerns that appear to be at odds with each other when trying to formulate a solution to the problem? **Aims:** • **Aim 8**: How do we safely dispose of medicinal nuclear waste? • **Aim 8**: The Pacific yew tree which is the source of the chemotherapy drug Taxol is facing extinction. • **Aim 8**: Solvent disposal is a growing environmental problem.

Additional higher level topics

Essential idea: Chiral auxiliaries allow the production of individual enantiomers of chiral molecules.

D.7 Taxol—a chiral auxiliary case study

Nature of science:

Advances in technology—many of these natural substances can now be produced in laboratories in high enough quantities to satisfy the demand. (3.7)

Risks and problems—the demand for certain drugs has exceeded the supply of natural substances needed to synthesize these drugs. (4.8)

Understandings:

- Taxol is a drug that is commonly used to treat several different forms of cancer.
- Taxol naturally occurs in yew trees but is now commonly synthetically produced.
- A chiral auxiliary is an optically active substance that is temporarily incorporated into an organic synthesis so that it can be carried out asymmetrically with the selective formation of a single enantiomer.

Applications and skills:

- Explanation of how taxol (paclitaxel) is obtained and used as a chemotherapeutic agent.
- Description of the use of chiral auxiliaries to form the desired enantiomer.
- Explanation of the use of a polarimeter to identify enantiomers.

Guidance:

- The structure of taxol is provided in the data booklet in section 37.

International-mindedness:

- There is an unequal availability and distribution of certain drugs and medicines around the globe.

Utilization:

Syllabus and cross-curricular links:
Topic 20.2—synthetic routes
Topic 20.3—stereoisomerism

Aims:

- **Aim 8**: Consider the ethical implications of using synthetic drugs instead of natural sources.

Essential idea: Nuclear radiation, whilst dangerous owing to its ability to damage cells and cause mutations, can also be used to both diagnose and cure diseases.

D.8 Nuclear medicine

Nature of science:

Risks and benefits—it is important to try and balance the risk of exposure to radiation with the benefit of the technique being considered. (4.8)

Understandings:

- Alpha, beta, gamma, proton, neutron and positron emissions are all used for medical treatment.
- Magnetic resonance imaging (MRI) is an application of NMR technology.
- Radiotherapy can be internal and/or external.
- Targeted Alpha Therapy (TAT) and Boron Neutron Capture Therapy (BNCT) are two methods which are used in cancer treatment.

Applications and skills:

- Discussion of common side effects from radiotherapy.
- Explanation of why technetium-99m is the most common radioisotope used in nuclear medicine based on its half-life, emission type and chemistry.
- Explanation of why lutetium-177 and yttrium-90 are common isotopes used for radiotherapy based on the type of radiation emitted.
- Balancing nuclear equations involving alpha and beta particles.
- Calculation of the percentage and amount of radioactive material decayed and remaining after a certain period of time using the nuclear half-life equation.
- Explanation of TAT and how it might be used to treat diseases that have spread throughout the body.

Guidance:

- Common side effects discussed should include hair loss, nausea, fatigue and sterility. Discussion should include the damage to DNA and growing or regenerating tissue.
- Isotopes used in nuclear medicine including; Tc-99m, Lu-177, Y-90, I-131 and Pb-212.

International-mindedness:

- The use of nuclear technology in medical treatments is not consistent across the globe. Culture, cost, availability and beliefs are some factors that can influence its use.

Theory of knowledge:

- There is often no reference to the term “nuclear” in MRI. Are names simply labels or do they influence our other ways of knowing? How does public perception influence scientific progress and implementation?

Utilization:

Syllabus and cross-curricular links:
Topics 11.3 and 21.1—NMR
Options C.3 and C.7—nuclear reactions and half-life
Physics option C.4—medical imaging.

Essential idea: A variety of analytical techniques is used for detection, identification, isolation and analysis of medicines and drugs.

<table>
<tr><th colspan="2">D.9 Drug detection and analysis</th></tr>
<tr><td colspan="2">Nature of science:
Advances in instrumentation—advances in technology (IR, MS and NMR) have assisted in drug detection, isolation and purification. (3.7)</td></tr>
<tr><td>Understandings:
• Organic structures can be analysed and identified through the use of infrared spectroscopy, mass spectroscopy and proton NMR.
• The presence of alcohol in a sample of breath can be detected through the use of either a redox reaction or a fuel cell type of breathalyser.
Applications and skills:
• Interpretation of a variety of analytical spectra to determine an organic structure including infrared spectroscopy, mass spectroscopy and proton NMR.
• Description of the process of extraction and purification of an organic product. Consider the use of fractional distillation, Raoult's law, the properties on which extractions are based and explaining the relationship between organic structure and solubility.
• Description of the process of steroid detection in sport utilizing chromatography and mass spectroscopy.
• Explanation of how alcohol can be detected with the use of a breathalyser.
Guidance:
• Students should be able to identify common organic functional groups in a given compound by recognition of common drug structures and from IR (section 26 of the data booklet), ^{1}H NMR (section 27 of the data booklet) and mass spectral fragment (section 28 of the data booklet) data.
• A common steroid structure is provided in section 34 in the data booklet.</td><td>International-mindedness:
• The misuse of drugs in sport is an international problem.
Theory of knowledge:
• Developments in technology have increased the chances of people being caught using illegal substances. How do changes in technology influence our ethical choices?
Utilization:
Syllabus and cross-curricular links:
Topic 10.2—functional groups
Aims:
• Aim 4: A variety of spectroscopy techniques can be used to identify newly developed molecules.
• Aim 7: Computer databases with spectroscopy data could be used to confirm the identity of newly synthesized molecules.
• Aim 8: Developments in technology have increased the chances of people being caught using illegal substances. How do changes in technology influence our ethical choices?</td></tr>
</table>

Assessment in the Diploma Programme

General

Assessment is an integral part of teaching and learning. The most important aims of assessment in the Diploma Programme are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessments are used in the Diploma Programme. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- Formative assessment informs both teaching and learning. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.
- Summative assessment gives an overview of previous learning and is concerned with measuring student achievement.

The Diploma Programme primarily focuses on summative assessment designed to record student achievement at, or towards the end of, the course of study. However, many of the assessment instruments can also be used formatively during the course of teaching and learning, and teachers are encouraged to do this. A comprehensive assessment plan is viewed as being integral with teaching, learning and course organization. For further information, see the IB *Programme standards and practices* (2010) document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the Diploma Programme please refer to the publication *Diploma Programme assessment: principles and practice* (2009).

To support teachers in the planning, delivery and assessment of the Diploma Programme courses, a variety of resources can be found on the OCC or purchased from the IB store (http://store.ibo.org). Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the OCC. Past examination papers as well as markschemes can be purchased from the IB store.

Methods of assessment

The IB uses several methods to assess work produced by students.

Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do, and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses.

Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

Analytic markschemes

Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response.

Marking notes

For some assessment components marked using assessment criteria, marking notes are provided. Marking notes give guidance on how to apply assessment criteria to the particular requirements of a question.

Inclusive assessment arrangements

Inclusive assessment arrangements are available for candidates with assessment access requirements. These arrangements enable candidates with diverse needs to access the examinations and demonstrate their knowledge and understanding of the constructs being assessed.

The IB document *Candidates with assessment access requirements* provides details on all the inclusive assessment arrangements available to candidates with learning support requirements. The IB document *Learning diversity and the IB programmes: Special educational needs within the International Baccalaureate programmes* outlines the position of the IB with regard to candidates with diverse learning needs in the IB programmes. For candidates affected by adverse circumstances, the IB documents *General regulations: Diploma Programme* (2011) and the *Handbook of procedures for the Diploma Programme* provide details on access consideration.

Responsibilities of the school

The school is required to ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity and the IB programmes: Special educational needs within the International Baccalaureate programmes*.

Assessment outline—SL

First assessment 2016

Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)
		1+2	3	
Paper 1	20	10	10	¾
Paper 2	40	20	20	1¼
Paper 3	20	10	10	1
Internal assessment	20	Covers objectives 1, 2, 3 and 4		10

Assessment outline—HL

First assessment 2016

Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)
		1+2	3	
Paper 1	20	10	10	1
Paper 2	36	18	18	2¼
Paper 3	24	12	12	1¼
Internal assessment	20	Covers objectives 1, 2, 3 and 4		10

External assessment

Detailed markschemes specific to each examination paper are used to assess students.

External assessment details—SL

Paper 1

Duration: 3/4 hour
Weighting: 20%
Marks: 30

- 30 multiple-choice questions on core, about 15 of which are common with HL.
- The questions on paper 1 test assessment objectives 1, 2 and 3.
- The use of calculators is not permitted.
- Students will be provided with a periodic table.
- No marks are deducted for incorrect answers.

Paper 2

Duration: 1¼ hours
Weighting: 40%
Marks: 50

- Short-answer and extended-response questions on core material.
- The questions on paper 2 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- A chemistry data booklet is to be provided by the school.

Paper 3

Duration: 1 hour
Weighting: 20%
Marks: 35

- This paper will have questions on core and SL option material.
- Section A: one data-based question and several short-answer questions on experimental work.
- Section B: short-answer and extended-response questions from one option.
- The questions on paper 3 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- A chemistry data booklet is to be provided by the school.

External assessment details—HL

Paper 1

Duration: 1 hour
Weighting: 20%
Marks: 40

- 40 multiple-choice questions on core and AHL, about 15 of which are common with SL.
- The questions on paper 1 test assessment objectives 1, 2 and 3.
- The use of calculators is not permitted.
- Students will be provided with a periodic table.
- No marks are deducted for incorrect answers.

Paper 2

Duration: 2¼ hours
Weighting: 36%
Marks: 95

- Short-answer and extended-response questions on the core and AHL material.
- The questions on paper 2 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- A chemistry data booklet is to be provided by the school.

Paper 3

Duration: 1¼ hours
Weighting: 24%
Marks: 45

- This paper will have questions on core, AHL and option material.
- Section A: one data-based question and several short-answer questions on experimental work.
- Section B: short-answer and extended-response questions from one option.
- The questions on paper 3 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- A chemistry data booklet is to be provided by the school.

Internal assessment

Purpose of internal assessment

Internal assessment is an integral part of the course and is compulsory for both SL and HL students. It enables students to demonstrate the application of their skills and knowledge, and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught.

The internal assessment requirements at SL and at HL are the same. This internal assessment section of the guide should be read in conjunction with the internal assessment section of the teacher support materials.

Guidance and authenticity

The work submitted for internal assessment must be the student's own work. However, it is not the intention that students should decide upon a title or topic and be left to work on the internal assessment component without any further support from the teacher. The teacher should play an important role during both the planning stage and the period when the student is working on the internally assessed work. It is the responsibility of the teacher to ensure that students are familiar with:

- the requirements of the type of work to be internally assessed
- the IB animal experimentation policy
- the assessment criteria—students must understand that the work submitted for assessment must address these criteria effectively.

Teachers and students must discuss the internally assessed work. Students should be encouraged to initiate discussions with the teacher to obtain advice and information, and students must not be penalized for seeking guidance. As part of the learning process, teachers should read and give advice to students on one draft of the work. The teacher should provide oral or written advice on how the work could be improved, but not edit the draft. The next version handed to the teacher must be the final version for submission.

It is the responsibility of teachers to ensure that all students understand the basic meaning and significance of concepts that relate to academic honesty, especially authenticity and intellectual property. Teachers must ensure that all student work for assessment is prepared according to the requirements and must explain clearly to students that the internally assessed work must be entirely their own. Where collaboration between students is permitted, it must be clear to all students what the difference is between collaboration and collusion.

All work submitted to the IB for moderation or assessment must be authenticated by a teacher, and must not include any known instances of suspected or confirmed academic misconduct. Each student must confirm that the work is his or her authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work it cannot be retracted. The requirement to confirm the authenticity of work applies to the work of all students, not just the sample work that will be submitted to the IB for the purpose of moderation. For further details refer to the IB publication *Academic honesty* (2011), *The Diploma Programme: From principles into practice* (2009) and the relevant articles in *General regulations: Diploma Programme* (2011).

Authenticity may be checked by discussion with the student on the content of the work, and scrutiny of one or more of the following:

- the student's initial proposal
- the first draft of the written work
- the references cited
- the style of writing compared with work known to be that of the student
- the analysis of the work by a web-based plagiarism detection service such as http://www.turnitin.com.

The same piece of work cannot be submitted to meet the requirements of both the internal assessment and the extended essay.

Group work

Each investigation is an individual piece of work based on different data collected or measurements generated. Ideally, students should work on their own when collecting data. In some cases, data collected or measurements made can be from a group experiment, provided each student collected his or her own data or made his or her own measurements. In chemistry, in some cases, group data or measurements may be combined to provide enough for individual analysis. Even in this case, each student should have collected and recorded their own data and they should clearly indicate which data are theirs.

It should be made clear to students that all work connected with the investigation should be their own. It is therefore helpful if teachers try to encourage in students a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work.

Time allocation

Internal assessment is an integral part of the chemistry course, contributing 20% to the final assessment in the SL and the HL courses. This weighting should be reflected in the time that is allocated to teaching the knowledge, skills and understanding required to undertake the work, as well as the total time allocated to carry out the work.

It is recommended that a total of approximately 10 hours of teaching time for both SL and HL should be allocated to the work. This should include:

- time for the teacher to explain to students the requirements of the internal assessment
- class time for students to work on the internal assessment component and ask questions
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

Safety requirements and recommendations

While teachers are responsible for following national or local guidelines, which may differ from country to country, attention should be given to the guidelines below, which were developed for the International Council of Associations for Science Education (ICASE) Safety Committee by The Laboratory Safety Institute (LSI).

It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

The Laboratory Safety Institute's Laboratory Safety Guidelines ...

40 suggestions for a safer lab

Steps Requiring Minimal Expense

1. Have a written health, safety and environmental affairs (HS&E) policy statement.
2. Organize a departmental HS&E committee of employees, management, faculty, staff and students that will meet regularly to discuss HS&E issues.
3. Develop an HS&E orientation for all new employees and students.
4. Encourage employees and students to care about their health and safety and that of others.
5. Involve every employee and student in some aspect of the safety program and give each specific responsibilities.
6. Provide incentives to employees and students for safety performance.
7. Require all employees to read the appropriate safety manual. Require students to read the institution's laboratory safety rules. Have both groups sign a statement that they have done so, understand the contents, and agree to follow the procedures and practices. Keep these statements on file in the department office.
8. Conduct periodic, unannounced laboratory inspections to identify and correct hazardous conditions and unsafe practices. Involve students and employees in simulated OSHA inspections.
9. Make learning how to be safe an integral and important part of science education, your work, and your life.
10. Schedule regular departmental safety meetings for all students and employees to discuss the results of inspections and aspects of laboratory safety.
11. When conducting experiments with hazards or potential hazards, ask yourself these questions:
    - What are the hazards?
    - What are the worst possible things that could go wrong?
    - How will I deal with them?
    - What are the prudent practices, protective facilities and equipment necessary to minimize the risk of exposure to the hazards?
12. Require that all accidents (incidents) be reported, evaluated by the departmental safety committee, and discussed at departmental safety meetings.
13. Require every pre-lab/pre-experiment discussion to include consideration of the health and safety aspects.
14. Don't allow experiments to run unattended unless they are failsafe.
15. Forbid working alone in any laboratory and working without prior knowledge of a staff member.
16. Extend the safety program beyond the laboratory to the automobile and the home.
17. Allow only minimum amounts of flammable liquids in each laboratory.
18. Forbid smoking, eating and drinking in the laboratory.
19. Do not allow food to be stored in chemical refrigerators.

20. Develop plans and conduct drills for dealing with emergencies such as fire, explosion, poisoning, chemical spill or vapour release, electric shock, bleeding and personal contamination.

21. Require good housekeeping practices in all work areas.

22. Display the phone numbers of the fire department, police department, and local ambulance either on or immediately next to every phone.

23. Store acids and bases separately. Store fuels and oxidizers separately.

24. Maintain a chemical inventory to avoid purchasing unnecessary quantities of chemicals.

25. Use warning signs to designate particular hazards.

26. Develop specific work practices for individual experiments, such as those that should be conducted only in a ventilated hood or involve particularly hazardous materials. When possible most hazardous experiments should be done in a hood.

Steps Requiring Moderate Expense

27. Allocate a portion of the departmental budget to safety.

28. Require the use of appropriate eye protection at all times in laboratories and areas where chemicals are transported.

29. Provide adequate supplies of personal protective equipment—safety glasses, goggles, face shields, gloves, lab coats and bench top shields.

30. Provide fire extinguishers, safety showers, eye wash fountains, first aid kits, fire blankets and fume hoods in each laboratory and test or check monthly.

31. Provide guards on all vacuum pumps and secure all compressed gas cylinders.

32. Provide an appropriate supply of first aid equipment and instruction on its proper use.

33. Provide fireproof cabinets for storage of flammable chemicals.

34. Maintain a centrally located departmental safety library:

    – “Safety in School Science Labs”, Clair Wood, 1994, Kaufman & Associates, 101 Oak Street, Wellesley, MA 02482

    – “The Laboratory Safety Pocket Guide”, 1996, Genium Publisher, One Genium Plaza, Schnectady, NY

    – “Safety in Academic Chemistry Laboratories”, ACS, 1155 Sixteenth Street NW, Washington, DC 20036

    – “Manual of Safety and Health Hazards in The School Science Laboratory”, “Safety in the School Science Laboratory”, “School Science Laboratories: A guide to Some Hazardous Substances” Council of State Science Supervisors (now available only from LSI.)

    – “Handbook of Laboratory Safety”, 4th Edition, CRC Press, 2000 Corporate Boulevard NW, Boca Raton, FL 33431

    – “Fire Protection Guide on Hazardous Materials”, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

    – “Prudent Practices in the Laboratory: Handling and Disposal of Hazardous Chemicals”, 2nd Edition, 1995

    – “Biosafety in the Laboratory”, National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418

    – “Learning By Accident”, Volumes 1-3, 1997-2000, The Laboratory Safety Institute, Natick, MA 01760

    (All are available from LSI.)

35. Remove all electrical connections from inside chemical refrigerators and require magnetic closures.

36. Require grounded plugs on all electrical equipment and install ground fault interrupters (GFIs) where appropriate.

37. Label all chemicals to show the name of the material, the nature and degree of hazard, the appropriate precautions, and the name of the person responsible for the container.

38. Develop a program for dating stored chemicals and for recertifying or discarding them after predetermined maximum periods of storage.

39. Develop a system for the legal, safe and ecologically acceptable disposal of chemical wastes.

40. Provide secure, adequately spaced, well ventilated storage of chemicals.

LSi
The Laboratory Safety Institute

Using assessment criteria for internal assessment

For internal assessment, a number of assessment criteria have been identified. Each assessment criterion has level descriptors describing specific achievement levels, together with an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Teachers must judge the internally assessed work at SL and at HL against the criteria using the level descriptors.

- Assessment criteria are the same for both SL and HL.
- The aim is to find, for each criterion, the descriptor that conveys most accurately the level attained by the student, using the best-fit model. A best-fit approach means that compensation should be made when a piece of work matches different aspects of a criterion at different levels. The mark awarded should be one that most fairly reflects the balance of achievement against the criterion. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.
- When assessing a student's work, teachers should read the level descriptors for each criterion until they reach a descriptor that most appropriately describes the level of the work being assessed. If a piece of work seems to fall between two descriptors, both descriptors should be read again and the one that more appropriately describes the student's work should be chosen.
- Where there are two or more marks available within a level, teachers should award the upper marks if the student's work demonstrates the qualities described to a great extent; the work may be close to achieving marks in the level above. Teachers should award the lower marks if the student's work demonstrates the qualities described to a lesser extent; the work may be close to achieving marks in the level below.
- Only whole numbers should be recorded; partial marks (fractions and decimals) are not acceptable.
- Teachers should not think in terms of a pass or fail boundary, but should concentrate on identifying the appropriate descriptor for each assessment criterion.

- The highest level descriptors do not imply faultless performance but should be achievable by a student. Teachers should not hesitate to use the extremes if they are appropriate descriptions of the work being assessed.
- A student who attains a high achievement level in relation to one criterion will not necessarily attain high achievement levels in relation to the other criteria. Similarly, a student who attains a low achievement level for one criterion will not necessarily attain low achievement levels for the other criteria. Teachers should not assume that the overall assessment of the students will produce any particular distribution of marks.
- It is recommended that the assessment criteria be made available to students.

Practical work and internal assessment

General introduction

The internal assessment requirements are the same for biology, chemistry and physics. The internal assessment, worth 20% of the final assessment, consists of one scientific investigation. The individual investigation should cover a topic that is commensurate with the level of the course of study.

Student work is internally assessed by the teacher and externally moderated by the IB. The performance in internal assessment at both SL and HL is marked against common assessment criteria, with a total mark out of 24.

> **Note:** Any investigation that is to be used to assess students should be specifically designed to match the assessment criteria.

The internal assessment task will be one scientific investigation taking about 10 hours and the write-up should be about 6 to 12 pages long. Investigations exceeding this length will be penalized in the communication criterion as lacking in conciseness.

The practical investigation, with generic criteria, will allow a wide range of practical activities satisfying the varying needs of biology, chemistry and physics. The investigation addresses many of the learner profile attributes well. See section on "Approaches to the teaching of chemistry" for further links.

The task produced should be complex and commensurate with the level of the course. It should require a purposeful research question and the scientific rationale for it. The marked exemplar material in the teacher support materials will demonstrate that the assessment will be rigorous and of the same standard as the assessment in the previous courses.

Some of the possible tasks include:

- a hands-on laboratory investigation
- using a spreadsheet for analysis and modelling
- extracting data from a database and analysing it graphically
- producing a hybrid of spreadsheet/database work with a traditional hands-on investigation
- using a simulation provided it is interactive and open-ended.

Some tasks may consist of relevant and appropriate qualitative work combined with quantitative work.

The tasks include the traditional hands-on practical investigations as in the previous course. The depth of treatment required for hands-on practical investigations is unchanged from the previous internal assessment and will be shown in detail in the teacher support materials. In addition, detailed assessment of specific aspects of hands-on practical work will be assessed in the written papers as detailed in the relevant topic(s) in the "Syllabus content" section of the guide.

The task will have the same assessment criteria for SL and HL. The five assessment criteria are personal engagement, exploration, analysis, evaluation and communication.

Internal assessment details

Internal assessment component

Duration: 10 hours

Weighting: 20%

- Individual investigation
- This investigation covers assessment objectives 1, 2, 3 and 4.

Internal assessment criteria

The new assessment model uses five criteria to assess the final report of the individual investigation with the following raw marks and weightings assigned:

Personal engagement	Exploration	Analysis	Evaluation	Communication	Total
2 (8%)	6 (25%)	6 (25%)	6 (25%)	4 (17%)	24 (100%)

Levels of performance are described using multiple indicators per level. In many cases the indicators occur together in a specific level, but not always. Also, not all indicators are always present. This means that a candidate can demonstrate performances that fit into different levels. To accommodate this, the IB assessment models use markbands and advise examiners and teachers to use a **best-fit approach** in deciding the appropriate mark for a particular criterion.

Teachers should read the guidance on using markbands shown above in the section called "Using assessment criteria for internal assessment" before starting to mark. It is also essential to be fully acquainted with the marking of the exemplars in the teacher support material. The precise meaning of the command terms used in the criteria can be found in the glossary of the subject guides.

Personal engagement

This criterion assesses the extent to which the student engages with the exploration and makes it their own. Personal engagement may be recognized in different attributes and skills. These could include addressing personal interests or showing evidence of independent thinking, creativity or initiative in the designing, implementation or presentation of the investigation.

Mark	Descriptor
0	The student’s report does not reach a standard described by the descriptors below.
1	**The evidence of personal engagement with the exploration is limited with little independent thinking, initiative or creativity**. The justification given for choosing the research question and/or the topic under investigation does not demonstrate **personal significance**, **interest or curiosity**. There is little evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation.
2	**The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or creativity.** The justification given for choosing the research question and/or the topic under investigation demonstrates **personal significance**, **interest or curiosity**. There is evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation.

Exploration

This criterion assesses the extent to which the student establishes the scientific context for the work, states a clear and focused research question and uses concepts and techniques appropriate to the Diploma Programme level. Where appropriate, this criterion also assesses awareness of safety, environmental, and ethical considerations.

Mark	Descriptor
0	The student’s report does not reach a standard described by the descriptors below.
1–2	The topic of the investigation is identified and a research question of some relevance is **stated but it is not focused**. The background information provided for the investigation is **superficial** or of limited relevance and does not aid the understanding of the context of the investigation. The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of limited awareness of the significant safety, ethical or environmental issues that are **relevant to the methodology of the investigation***.
3–4	The topic of the investigation is identified and a relevant but not fully focused research question is described. The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation. The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of some awareness of the significant safety**,** ethical or environmental issues that are **relevant to the methodology of the investigation.***

Mark	Descriptor
5–6	The topic of the investigation is identified and a relevant and fully focused research question is clearly described. The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation. The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of full awareness of the significant safety, ethical or environmental issues that are **relevant to the methodology of the investigation**.*

* This indicator should only be applied when appropriate to the investigation. See exemplars in TSM.

Analysis

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	The report includes **insufficient relevant** raw data to support a valid conclusion to the research question. Some **basic** data processing is carried out but is either too **inaccurate or too insufficient to lead to a valid** conclusion. The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis. The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
3–4	The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question. Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing. The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis. The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.
5–6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question. Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data. The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.

Evaluation

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	A conclusion is **outlined** which is not relevant to the research question or is not supported by the data presented. The conclusion makes superficial comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **outlined** but are restricted to an **account** of **the practical** or **procedural issues** faced. The student has **outlined** very few realistic and relevant suggestions for the improvement and extension of the investigation.
3–4	A conclusion is **described** which is relevant to the research question and supported by the data presented. A conclusion is described which makes some relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues*** involved in establishing the conclusion. The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation.
5–6	A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented. A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues*** involved in establishing the conclusion. The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation.

*See exemplars in TSM for clarification.

Communication

This criterion assesses whether the investigation is presented and reported in a way that supports effective communication of the focus, process and outcomes.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	**The presentation of the investigation is unclear, making it difficult to understand the focus, process and outcomes.** The report is not well structured and is unclear: the necessary information on focus, process and outcomes is missing or is presented in an incoherent or disorganized way. The understanding of the focus, process and outcomes of the investigation is obscured by the presence of inappropriate or irrelevant information. There are many errors in the use of subject specific terminology and conventions*.
3–4	**The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes**. The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way. The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation. The use of subject specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding.

*For example, incorrect/missing labelling of graphs, tables, images; use of units, decimal places. For issues of referencing and citations refer to the "Academic honesty" section.

Rationale for practical work

Although the requirements for IA are centred on the investigation, the different types of practical activities that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of much scientific work
- developing an appreciation of scientists' use of secondary data from databases
- developing an appreciation of scientists' use of modelling
- developing an appreciation of the benefits and limitations of scientific methodology.

Practical scheme of work

The practical scheme of work (PSOW) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. Students at SL and HL in the same subject may carry out some of the same investigations.

Syllabus coverage

The range of practical work carried out should reflect the breadth and depth of the subject syllabus at each level, but it is not necessary to carry out an investigation for every syllabus topic. However, all students must participate in the group 4 project and the IA investigation.

Planning your practical scheme of work

Teachers are free to formulate their own practical schemes of work by choosing practical activities according to the requirements outlined. Their choices should be based on:

- subjects, levels and options taught
- the needs of their students
- available resources
- teaching styles.

Each scheme must include some complex experiments that make greater conceptual demands on students. A scheme made up entirely of simple experiments, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the online curriculum centre (OCC) to share ideas about possible practical activities by joining in the discussion forums and adding resources in the subject home pages.

Flexibility

The practical programme is flexible enough to allow a wide variety of practical activities to be carried out. These could include:

- short labs or projects extending over several weeks
- computer simulations
- using databases for secondary data
- developing and using models
- data-gathering exercises such as questionnaires, user trials and surveys
- data-analysis exercises
- fieldwork.

Practical work documentation

Details of the practical scheme of work are recorded on *Form 4/PSOW* provided in the *Handbook of procedures*. A copy of the class *4/PSOW* form must be included with any sample set sent for moderation.

Time allocation for practical work

The recommended teaching times for all Diploma Programme courses are 150 hours at SL and 240 hours at HL. Students at SL are required to spend 40 hours, and students at HL 60 hours, on practical activities (excluding time spent writing up work). These times include 10 hours for the group 4 project and 10 hours for the internal assessment investigation. (Only 2–3 hours of investigative work can be carried out after the deadline for submitting work to the moderator and still be counted in the total number of hours for the practical scheme of work.)

The group 4 project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students from the different group 4 subjects analyse a common topic or problem. The exercise should be a collaborative experience where the emphasis is on the processes involved in, rather than the products of, such an activity.

In most cases students in a school would be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics—that is, there may be several group 4 projects in the same school.

Students studying environmental systems and societies are not required to undertake the group 4 project.

Summary of the group 4 project

The group 4 project is a collaborative activity where students from different group 4 subjects work together on a scientific or technological topic, allowing for concepts and perceptions from across the disciplines to be shared in line with aim 10—that is, to "develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge". The project can be practically or theoretically based. Collaboration between schools in different regions is encouraged.

The group 4 project allows students to appreciate the environmental, social and ethical implications of science and technology. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The choice of scientific or technological topic is open but the project should clearly address aims 7, 8 and 10 of the group 4 subject guides.

Ideally, the project should involve students collaborating with those from other group 4 subjects at all stages. To this end, it is not necessary for the topic chosen to have clearly identifiable separate subject components. However, for logistical reasons, some schools may prefer a separate subject "action" phase (see the following "Project stages" section).

Project stages

The 10 hours allocated to the group 4 project, which are part of the teaching time set aside for developing the practical scheme of work, can be divided into three stages: planning, action and evaluation.

Planning

This stage is crucial to the whole exercise and should last about two hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all group 4 students meeting to "brainstorm" and discuss the central topic, sharing ideas and information.

- The topic can be chosen by the students themselves or selected by the teachers.
- Where large numbers of students are involved, it may be advisable to have more than one mixed subject group.

After selecting a topic or issue, the activities to be carried out must be clearly defined before moving from the planning stage to the action and evaluation stages.

A possible strategy is that students define specific tasks for themselves, either individually or as members of groups, and investigate various aspects of the chosen topic. At this stage, if the project is to be experimentally based, apparatus should be specified so that there is no delay in carrying out the action stage. Contact with other schools, if a joint venture has been agreed, is an important consideration at this time.

Action

This stage should last around six hours and may be carried out over one or two weeks in normal scheduled class time. Alternatively, a whole day could be set aside if, for example, the project involves fieldwork.

- Students should investigate the topic in mixed-subject groups or single subject groups.
- There should be collaboration during the action stage; findings of investigations should be shared with other students within the mixed/single-subject group. During this stage, in any practically based activity, it is important to pay attention to safety, ethical and environmental considerations.

Note: Students studying two group 4 subjects are not required to do two separate action phases.

Evaluation

The emphasis during this stage, for which two hours are probably necessary, is on students sharing their findings, both successes and failures, with other students. How this is achieved can be decided by the teachers, the students or jointly.

- One solution is to devote a morning, afternoon or evening to a symposium where all the students, as individuals or as groups, give brief presentations.
- Alternatively, the presentation could be more informal and take the form of a science fair where students circulate around displays summarizing the activities of each group.

The symposium or science fair could also be attended by parents, members of the school board and the press. This would be especially pertinent if some issue of local importance has been researched. Some of the findings might influence the way the school interacts with its environment or local community.

Addressing aims 7 and 8

Aim 7: "develop and apply 21st century communication skills in the study of science."

Aim 7 may be partly addressed at the planning stage by using electronic communication within and between schools. It may be that technology (for example, data logging, spreadsheets, databases and so on) will be used in the action phase and certainly in the presentation/evaluation stage (for example, use of digital images, presentation software, websites, digital video and so on).

Aim 8: "become critically aware, as global citizens, of the ethical implications of using science and technology."

Addressing the international dimension

There are also possibilities in the choice of topic to illustrate the international nature of the scientific endeavour and the increasing cooperation required to tackle global issues involving science and technology. An alternative way to bring an international dimension to the project is to collaborate with a school in another region.

Types of project

While addressing aims 7, 8 and 10 the project must be based on science or its applications. The project may have a hands-on practical action phase or one involving purely theoretical aspects. It could be undertaken in a wide range of ways:

- designing and carrying out a laboratory investigation or fieldwork.
- carrying out a comparative study (experimental or otherwise) in collaboration with another school.
- collating, manipulating and analysing data from other sources, such as scientific journals, environmental organizations, science and technology industries and government reports.
- designing and using a model or simulation.
- contributing to a long-term project organized by the school.

Logistical strategies

The logistical organization of the group 4 project is often a challenge to schools. The following models illustrate possible ways in which the project may be implemented.

Models A, B and C apply within a single school, and model D relates to a project involving collaboration between schools.

Model A: mixed-subject groups and one topic

Schools may adopt mixed-subject groups and choose one common topic. The number of groups will depend on the number of students.

Model B: mixed-subject groups adopting more than one topic

Schools with large numbers of students may choose to do more than one topic.

Model C: single-subject groups

For logistical reasons some schools may opt for single-subject groups, with one or more topics in the action phase. This model is less desirable as it does not show the mixed subject collaboration in which many scientists are involved.

Model D: collaboration with another school

The collaborative model is open to any school. To this end, the IB provides an electronic collaboration board on the OCC where schools can post their project ideas and invite collaboration from other schools. This could range from merely sharing evaluations for a common topic to a full-scale collaborative venture at all stages.

For schools with few Diploma Programme (course) students it is possible to work with non-Diploma Programme or non-group 4 students or undertake the project once every two years. However, these schools are encouraged to collaborate with another school. This strategy is also recommended for individual students who may not have participated in the project, for example, through illness or because they have transferred to a new school where the project has already taken place.

Timing

The 10 hours that the IB recommends be allocated to the project may be spread over a number of weeks. The distribution of these hours needs to be taken into account when selecting the optimum time to carry out the project. However, it is possible for a group to dedicate a period of time exclusively to project work if all/most other schoolwork is suspended.

Year 1

In the first year, students' experience and skills may be limited and it would be inadvisable to start the project too soon in the course. However, doing the project in the final part of the first year may have the advantage of reducing pressure on students later on. This strategy provides time for solving unexpected problems.

Year 1–Year 2

The planning stage could start, the topic could be decided upon, and provisional discussion in individual subjects could take place at the end of the first year. Students could then use the vacation time to think about how they are going to tackle the project and would be ready to start work early in the second year.

Year 2

Delaying the start of the project until some point in the second year, particularly if left too late, increases pressure on students in many ways: the schedule for finishing the work is much tighter than for the other options; the illness of any student or unexpected problems will present extra difficulties. Nevertheless, this choice does mean students know one another and their teachers by this time, have probably become accustomed to working in a team and will be more experienced in the relevant fields than in the first year.

Combined SL and HL

Where circumstances dictate that the project is only carried out every two years, HL beginners and more experienced SL students can be combined.

Selecting a topic

Students may choose the topic or propose possible topics and the teacher then decides which one is the most viable based on resources, staff availability and so on. Alternatively, the teacher selects the topic or proposes several topics from which students make a choice.

Student selection

Students are likely to display more enthusiasm and feel a greater sense of ownership for a topic that they have chosen themselves. A possible strategy for student selection of a topic, which also includes part of the planning stage, is outlined here. At this point, subject teachers may provide advice on the viability of proposed topics.

- Identify possible topics by using a questionnaire or a survey of students.
- Conduct an initial “brainstorming” session of potential topics or issues.
- Discuss, briefly, two or three topics that seem interesting.
- Select one topic by consensus.
- Students make a list of potential investigations that could be carried out. All students then discuss issues such as possible overlap and collaborative investigations.

A reflective statement written by each student on their involvement in the group 4 project must be included on the coversheet for each internal assessment investigation. See *Handbook of procedures* for more details.

Glossary of command terms

Command terms for chemistry

Students should be familiar with the following key terms and phrases used in examination questions, which are to be understood as described below. Although these terms will be used frequently in examination questions, other terms may be used to direct students to present an argument in a specific way.

These command terms indicate the depth of treatment required.

Assessment objective 1

Command term	Definition
Classify	Arrange or order by class or category.
Define	Give the precise meaning of a word, phrase, concept or physical quantity.
Draw	Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.
Label	Add labels to a diagram.
List	Give a sequence of brief answers with no explanation.
Measure	Obtain a value for a quantity.
State	Give a specific name, value or other brief answer without explanation or calculation.

Assessment objective 2

Command term	Definition
Annotate	Add brief notes to a diagram or graph.
Apply	Use an idea, equation, principle, theory or law in relation to a given problem or issue.
Calculate	Obtain a numerical answer showing the relevant stages in the working.
Describe	Give a detailed account.
Distinguish	Make clear the differences between two or more concepts or items.
Estimate	Obtain an approximate value.
Formulate	Express precisely and systematically the relevant concept(s) or argument(s).

Command term	Definition
Identify	Provide an answer from a number of possibilities.
Outline	Give a brief account or summary.

Assessment objective 3

Command term	Definition
Analyse	Break down in order to bring out the essential elements or structure.
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of the similarities between two (or more) items or situations, referring to both (all) of them throughout.
Compare and contrast	Give an account of similarities and differences between two (or more) items or situations, referring to both (all) of them throughout.
Construct	Display information in a diagrammatic or logical form.
Deduce	Reach a conclusion from the information given.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
Derive	Manipulate a mathematical relationship to give a new equation or relationship.
Design	Produce a plan, simulation or model.
Determine	Obtain the only possible answer.
Discuss	Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.
Evaluate	Make an appraisal by weighing up the strengths and limitations.
Examine	Consider an argument or concept in a way that uncovers the assumptions and interrelationships of the issue.
Explain	Give a detailed account including reasons or causes.
Explore	Undertake a systematic process of discovery.
Interpret	Use knowledge and understanding to recognize trends and draw conclusions from given information.
Justify	Give valid reasons or evidence to support an answer or conclusion.
Predict	Give an expected result.
Show	Give the steps in a calculation or derivation.
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.

Command term	Definition
Solve	Obtain the answer(s) using algebraic and/or numerical and/or graphical methods.
Suggest	Propose a solution, hypothesis or other possible answer.

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This bibliography lists the principal works used to inform the curriculum review. It is not an exhaustive list and does not include all the literature available: judicious selection was made in order to better advise and guide teachers. This bibliography is not a list of recommended textbooks.

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IB DP Chemistry Prescribed practicals lab manual

Note to teachers: I've shared this lab manual in the hope that it will be useful for new (or old) teachers to give some ideas for the labs for the prescribed practicals.

It is not a definite list by all means and if there are errors or omissions, then I'd be glad to hear of them. Teachers should feel free to edit this lab manual as they see fit. If I have violated any copyright, then let me know and I will make every effort to remedy it.

It's also worth mentioning that I take no responsibility for any of the experimental methods in this lab manual; it's up to individual teachers to ensure that the methods are safe.

Michael Sugiyama Jones
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Prescribed practicals

Included in the "Applications and skills" sections of the guide are a series of practicals that students must cover either in a laboratory environment or as a simulation. The skills and general techniques associated with these common practicals may be assessed as part of the external assessment. The list of required practicals for chemistry is shown in the table below with suggested practicals.

Topic 1.2	**Obtaining and using experimental data for deriving empirical formulas from reactions involving mass changes.**
	Determine the formula of MgO Determine the formula of hydrated copper sulfate
Topic 1.3	**Use of the experimental method of titration to calculate the concentration of a solution by reference to a standard solution.**
	Preparation of a standard solution/acid base titration Determine the percentage $CaCO_3$ in eggshells
Topic 1.3	**Obtaining and using experimental values to calculate the molar mass of a gas from the ideal gas equation.**
	Determine the molar mass of a gas (CO_2) experimentally
Topic 5.1	**A calorimetry experiment for an enthalpy of reaction should be covered and the results evaluated.**
	Calculate enthalpy change of neutralisation (HCl and NaOH) Calculate enthalpy change Zn and $CuSO_4$
Topic 6.1	**Investigation of rates of reaction experimentally and evaluation of results.**
	Sodium thiosulfate and hydrochloric acid reaction Iodine clock reaction
Topic 8.2	**Candidates should have experience of acid–base titrations with different indicators.**
	Covered in topic 1.3
Topic 8.3	**Students should be familiar with the use of a pH meter and universal indicator.**
	Reactions of acid and bases lab
Topic 9.2	**Performance of laboratory experiments involving a typical voltaic cell using two metal/metal–ion half-cells.**
	Voltaic cell with Zn and Cu half-cells
Topic 10.1	**Construction of 3D models (real or virtual) of organic molecules.**
	Molecular shapes simulation https://phet.colorado.edu/en/simulation/molecule-shapes Molymods http://www.molymod.com/ Chemdoodle https://www.chemdoodle.com/
Topic 19.1	**Perform lab experiments which could include single replacement reactions in aqueous solutions.**
	Displacement reactions

Topic 1.2 Obtaining and using experimental data for deriving empirical formulas from reactions involving mass changes.

Title: Determine the empirical formula of MgO experimentally

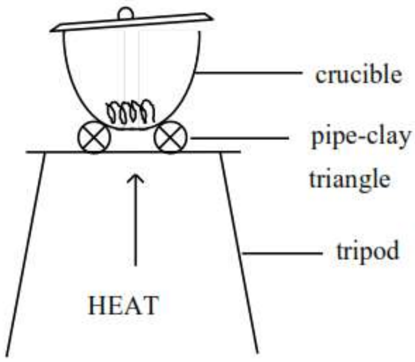
Background: When magnesium is heated in air, it reacts with oxygen. During this oxidation reaction, magnesium oxide is produced. This increases the mass. If we know the mass of magnesium at the start, and the mass of magnesium oxide produced at the end, we can calculate the mass of oxygen which has been combined with the magnesium. We can use these masses to determine the empirical formula of magnesium oxide.

Procedure:

1. Record the mass of the empty crucible with its lid, and write down the result in a table.
2. Clean the piece of magnesium ribbon with sandpaper, then coil it loosely around a pencil.
3. Put the magnesium ribbon into the crucible and put the lid on. Record the mass of the crucible, lid, and magnesium together, and write down the result in your table.
4. Put the crucible onto the pipe-clay triangle. Leave the lid slightly ajar to allow air into the crucible. Heat gently for a minute, then strongly. Continue heating until the reaction has finished (the magnesium will glow at first, then look a bit like a furry grey-black caterpillar)
5. Turn the gas burner off, and allow the crucible to cool for a few minutes. Record the mass of the crucible with its lid and contents.

Results:

	Mass (±0.01g)
crucible + lid	
crucible + lid + magnesium	
crucible + lid + contents after reaction	



Calculations:

1) Calculate the mass of magnesium (mass of crucible + lid – mass of crucible + lid + magnesium)

2) Calculate the mass of oxygen that reacted with the magnesium (mass of crucible, lid and contents after reaction – mass of crucible + lid + magnesium).

3) Calculate amount (in mol) of magnesium and oxygen.

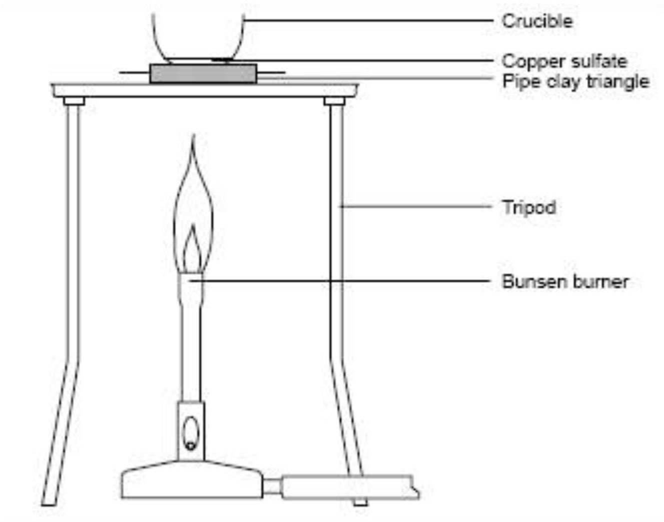
4) Determine the lowest whole number ratio of Mg to O (empirical formula)

Title: Determine the formula of hydrated copper(II) sulfate

Background: Many crystals occur commonly in hydrated form, which means that they contain water molecules within the crystal structure in definite proportions. This water is called water of crystallization. The formula for these crystals shows the number of water molecules present per formula unit of crystal using a dot before the water. When these crystals are heated, they lose their water of crystallization and are then said to be anhydrous.

Procedure:

1. Weigh the empty crucible, and then weigh into it between 2.00 g and 3.00 g of hydrated copper(II) sulfate. Record all masses accurate to the nearest 0.01 g.
2. Support the crucible securely in the pipe-clay triangle on the tripod over the Bunsen burner.



3. Heat the crucible and contents, gently at first, over a medium Bunsen flame, so that the water of crystallisation is driven off steadily. The blue colour of the hydrated compound should gradually fade to the greyish-white of anhydrous copper(II) sulfate. **Avoid over-heating, which may cause further decomposition, and stop heating immediately if the colour starts to blacken. If over-heated, toxic or corrosive fumes may be evolved**.
4. Allow the crucible and contents to cool. Re-weigh the crucible and contents once cold.
5. ‘Heat to constant mass’ by repeating steps (iii) and (iv) until you get consistent readings.

Results:

	Mass (±0.01 g)	Observations
Mass of crucible + lid		
Mass of crucible + lid + $CuSO_4.xH_2O$ before heating		
Mass of crucible + lid + $CuSO_4$(anhydrous) after heating		

Calculations:

1. Calculate the molar masses of H_2O and $CuSO_4$ (Relative atomic masses: H=1.01, O=16.00, S=32.06, Cu=63.55).
2. Calculate the mass of water driven off, and the mass of anhydrous copper(II) sulfate formed in your experiment.
3. Calculate the number of moles of anhydrous copper(II) sulfate formed
4. Calculate the number of moles of water driven off.
5. Calculate how many moles of water would have been driven off if one mole of anhydrous copper(II) sulfate had been formed.
6. Determine the formula for hydrated copper(II) sulfate.

Topic 1.3 Use of the experimental method of titration to calculate the concentration of a solution by reference to a standard solution.

Title: Preparation of a standard solution

Background: Standard solutions are solutions with known concentrations, generally to four significant figures. There are two different ways to make a standard solution. We can make a primary or a secondary standard. A primary standard is prepared directly by dissolving a known mass of sample to make a known volume of solution. A secondary standard is prepared by dissolving an approximate amount of sample into a volume of solvent and determining its exact concentration through titration experiments. Primary standards are prepared from compounds that are at least **99.9% pure**, have a **definite composition**, are **water soluble**, are **easily weighed**, and **do not change composition on contact with air**. Oxalic acid dihydrate ($H_2C_2O_4 \bullet 2H_2O$) fits these criteria and therefore may be used as a primary standard. Sodium hydroxide absorbs water when it comes into contact with air and therefore it is difficult to obtain a pure, dry sample to weigh. For this reason, the sodium hydroxide solution will be titrated with the oxalic acid standard to become a secondary standard.

In the first part of this experiment you will prepare a solution of known concentration of oxalic acid. The oxalic acid crystallizes with two water molecules per oxalic acid in the crystalline network. For this reason, we will weigh out an appropriate amount of oxalic acid dehydrate to dissolve in water. The water molecules in the crystal network will become part of the water of solution once it is dissolved. The molar concentration of oxalic acid dihydrate will be the same as the molar concentration of oxalic acid.

Preparation of primary standard

Procedure:

1. Obtain a 100 cm^3 beaker.
2. Measure between 1.25 g and 1.30 g of pure oxalic acid dehydrate crystals and place into the beaker.
3. Add approximately 30 cm^3 of deionized water to the beaker and dissolve the crystals.
4. Transfer the solution into a clean 100.00 cm^3 volumetric flask.
5. Rinse the beaker with 20 cm^3 of deionized water and pour this solution into the volumetric flask and repeat. This will ensure that all of the oxalic acid is transferred into the volumetric flask.
6. Fill the volumetric flask to within about 2 cm^3 of the mark and allow it to sit for a minute. This will allow any water clinging to the edges of the neck to drain into the flask.
7. Using a pipette, fill the flask to the 100.00 cm^3 mark with water.
8. Stopper the flask and mix the solution by repeated inversion and swirling.

Calculations:

Mass of oxalic acid =

1. Calculate moles of oxalic acid

2. Calculate the concentration of the oxalic acid solution using the equation C= n/V (don't forget the uncertainty)

Standardisation of sodium hydroxide solution

In order to standardize the sodium hydroxide solution, you will perform a titration. Sodium hydroxide reacts with oxalic acid according to the reaction below:

$$H_2C_2O_{4(aq)} + 2NaOH_{(aq)} \rightarrow 2H_2O_{(l)} + Na_2C_2O_{4(aq)}$$

You will measure a 20.00 cm^3 aliquot (an aliquot is an exact quantity of a substance or solution) of the oxalic acid solution into a flask and add an indicator. An indicator is a substance that changes colour when a solution changes from acidic to basic. The common indicator used for acid base titrations is phenolphthalein. Phenolphthalein is colourless in a solution that is acidic and bright pink in a solution that is basic. In this titration the oxalic acid solution is acidic and therefore phenolphthalein will be colourless. The sodium hydroxide solution will be added drop wise from a burette into the flask containing the oxalic acid and indicator. As the sodium hydroxide is added to the flask it will react with the oxalic acid and be neutralized. At the point where all of the oxalic acid is reacted, the next drop of sodium hydroxide will make the entire solution basic and it will turn pink. At this point you have completed the titration. In order to get the best precision possible, you should repeat each titration until you get 3 trials that are within 0.10 cm^3 of each other (concordant).

Results

	Trial 1 (rough)	Trial 2	Trial 3	Trial 4
Volume of oxalic acid solution ± 0.08 cm^3	20.00	20.00	20.00	20.00
NaOH buret, initial volume reading ± 0.05 cm^3				
NaOH buret, final reading ± 0.05 cm^3				
Volume of NaOH solution used ± 0.10 cm^3				

Calculations:

1. Calculate the average volume of NaOH solution used (choose values within 0.10 cm^3)

2. Calculate number of moles of oxalic acid in 20 cm^3 of oxalic acid solution.

3. Use the ratio of NaOH to $H_2C_2O_4$ to find number of moles of NaOH.

4. Use the equation C=n/V to find concentration of NaOH solution

Title: Determine the percentage of calcium carbonate in egg shells

Background: In this experiment, you will determine the percentage of calcium carbonate in an egg shell. Calcium carbonate reacts with hydrochloric acid according to the following equation:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

It is difficult to determine exactly when all the solid calcium carbonate has reacted to one drop of standard hydrochloric acid solution if it is titrated directly. In this experiment a known amount of excess acid is added to the sample to ensure that all the calcium carbonate has reacted. The excess acid is then diluted and made up to a known volume. Aliquots of this diluted excess acid solution are then titrated with a standard solution of sodium hydroxide.

Procedure:

1. Clean and dry an eggshell, removing as much of the egg membrane as possible.
2. Weigh 0.60 g of crushed eggshell and place in a conical flask.
3. Slowly add 20.00 cm^3 of 1.00 mol dm^{-3} HCl to the egg shell in the conical flask.
4. When the reaction has finished, add about 20 cm^3 of distilled water to the solution.
5. Transfer the solution to a 100.00 cm^3 volumetric flask and make up to 100.00 cm^3 with distilled water.
6. Measure 10.00 cm^3 of this solution and place in a clean conical flask.
7. Add a few drops of phenolphthalein indicator and titrate with 0.100 mol dm^{-3} NaOH.

Results:

Trial	1 (rough)	2	3	4	5
Initial volume of NaOH (±0.05 cm^3)					
Final volume NaOH (±0.05 cm^3)					
Total volume NaOH used (±0.10 cm^3)					
Colour change					

Choose results that are within 0.10 cm^3 of each other and calculate the average volume of NaOH used.

Average volume of NaOH =

Calculations:

1. Calculate the amount (in mol) of hydrochloric acid present initially in 20.00 cm^3 of 1.00 mol dm^{-3} $HCl_{(aq)}$

2. Calculate the amount of sodium hydroxide (in mol) present in the volume of 0.100 mol dm^{-3} $NaOH_{(aq)}$ used for the titration.

3. Determine the amount (in mol) of unreacted $HCl_{(aq)}$ present in the 10.00 cm^3 sample.

4. Determine the amount (in mol) of unreacted $HCl_{(aq)}$ present in the 100 cm^3 solution.

5. Determine the amount (in mol) of $HCl_{(aq)}$ that reacted with the egg shell.

6. Calculate the amount (in mol) of calcium carbonate present in the egg shell.

7. Calculate the mass of calcium carbonate present in the egg shell.

8. Determine the percentage by mass of calcium carbonate in the egg shell.

9. Determine the total percentage uncertainty associated with your result.

Topic 1.3 Obtaining and using experimental values to calculate the molar mass of a gas from the ideal gas equation.

Title: Determine the molar mass of CO_2 experimentally

Background: In this lab, we are going to determine the molar mass of CO_2 experimentally. A simple calculation using a periodic table would give us the correct answer for the molar mass of CO_2, however, you are going to conduct an experiment in the lab to see how close you can come to the accepted value. The ideal gas law equation (*PV = nRT*) can be rearranged to solve for *n*, the amount in moles:

$$n=PVRT$$

Molar mass (M), is expressed in units of grams per mole ($gmol^{-1}$). The mass of the CO_2 released from the pressurized container the volume of the gas will be measured. You can use the method of water displacement at room conditions and then substitute the measurements of volume, temperature, and pressure into the ideal gas law equation in order to find *n*, the number of moles of CO_2. Once we know the mass, and the number of moles, we will divide the mass by the number of moles to calculate the molar mass ($gmol^{-1}$).

Procedure:

1. Determine the initial mass for the CO_2 canister provided by your instructor (± .01 gram).
2. Set up the water basin for collecting a gas in an inverted graduated cylinder by water displacement. Use a 100 cm^3 graduated cylinder.
3. Release CO_2 from the pressurized container and collect a sample of gas with a volume of approximately 70.0 cm^3 to 90.0 cm^3. <u>Collect every bubble that leaves the canister</u>.
4. Adjust the cylinder up or down so that the water level inside the graduated cylinder is the same as the level outside the cylinder. **THIS IS VERY IMPORTANT!** If you miss this simple step, the pressures inside and outside the cylinder will not be equal, and you will have an inaccurate estimation of the pressure inside the cylinder where the gas is collected.
5. Record the volume of CO_2 that was collected in the Observations and Data section.
6. Measure and record the temperature of the water in the basin (±0.1 °C). This will be used to determine the vapour pressure of water $H_2O_{(g)}$ in the graduated cylinder.
7. Read the air pressure in the lab and convert this to Pa.
8. Measure and record the mass of the CO_2 canister after your experiment. (±0.01 g).

Results and calculations:

Mass

Initial mass of CO_2 container ($m_{initial}$) = _____________

Final mass of CO_2 container (m_{final}) = _____________

Mass of CO_2 collected ($m_{initial}$ - m_{final}) = _____________

Volume

Volume of the gas collected (cm^3) = ____________

Volume of CO_2, converted to m^3 ($cm^3 \div 10^6$) = _____________

Temperature

Temperature of water in basin (^oC) = _____________

Temperature of water in kelvin (K) = _____________

(assume that the water and the CO_2 are the same temperature)

Temperature of CO_2 (K) = _____________

Pressure

Air pressure in the room (Pa) = ______________

Vapour pressure of water = ______________

The gas collected in the cylinder is a mixture of CO_2 and H_2O

Use Dalton's law of partial pressure to calculate the pressure of the CO_2 in the mixture

$P_{total} = P_{CO_2} + P_{water\ vapour}$ (Pa)________________

Pressure of dry CO_2 (Pa) = ______________

1. Calculate the amount (in mol) of CO_2 collected using the equation:

n=PVRT

2. Determine the experimental molar mass of the CO_2 using the equation M = m ÷ n

3. Determine the molar mass of CO_2 using a periodic table.

4. Calculate the % error and suggest reasons for this error.

Topic 5.1 A calorimetry experiment for an enthalpy of reaction should be covered and the results evaluated.

Title: Determine the enthalpy change for reaction of Zn and $CuSO_4$

Background: Chemical reactions can be classified as exothermic or endothermic depending on whether they have a negative or positive enthalpy change. In this experiment, you will calculate the enthalpy change for the following reaction:

$$Zn_{(s)} + CuSO_{4(aq)} \; ZnSO_{4(aq)} + Cu_{(s)}$$

Procedure:

1. Using a $50.0 cm^3$ measuring cylinder, measure $50.0\ cm^3$ of $0.500\ mol\ dm^{-3}$ $CuSO_4$ and pour into an insulated cup.
2. Using a mass balance, measure 3.00g of Zn powder.
3. Insert a temperature probe into the $CuSO_4$, start the data collection, and record the temperature every 30 seconds.
4. At 3 minutes (180 seconds), add the 3.00 g of Zn powder to the insulated cup containing the $CuSO_4$, and stir gently.
5. Continue to record the temperature every 30 seconds for a further 6 minutes (360 seconds).

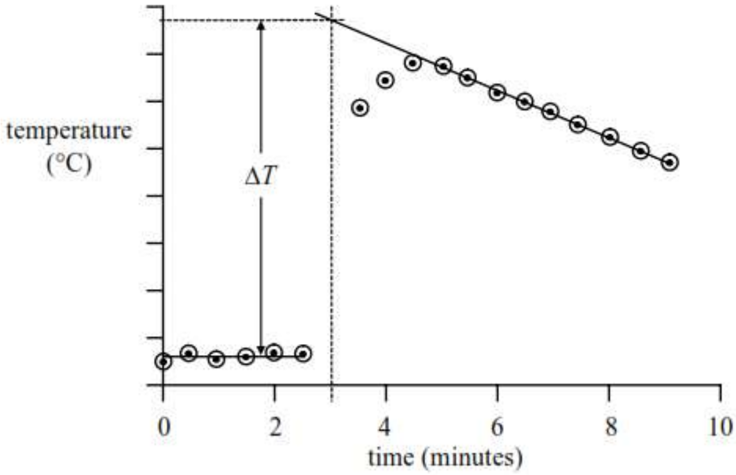
Results:

Time (min)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
Temperature (°C)							**not done**			
Time (min)	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5
Temperature (°C)										

Analysis:

Plot a graph of temperature (y axis) against time (x axis)

Extrapolate the curve back to 3.0 minutes to establish the maximum temperature rise as shown in the example below:



Calculations:

1. Calculate the heat (Q) released using the formula:

$$Q = mc\Delta T$$

m = mass of solution (g)
c = specific heat capacity of water = 4.18 J g^{-1} $^{o}C^{-1}$
ΔT = change in temperature (^{o}C)

2. Calculate the enthalpy change for the reaction between one mole of Zn and $CuSO_{4(aq)}$

3. The literature value for the reaction is – 217 kJ mol^{-1}
   Calculate the percentage error using the following equation:

% error = experimental value−literature valueliterature value × 100

Title: Calculating the enthalpy change of neutralisation

Background: The enthalpy change of neutralisation (ΔH_n) is the enthalpy change when an acid and base react together to form one mole of water under standard conditions (100 kPa and 298 K). In this experiment you will calculate the enthalpy change of neutralisation between a strong acid hydrochloric acid (HCl) and strong base sodium hydroxide (NaOH).

Procedure:

1. Using a measuring cylinder, measure 30 cm^3 of 1.00 $moldm^{-3}$ HCl (hydrochloric acid) and pour into an insulated cup. Record the mass of the solution.
2. Insert a temperature probe into the cup and wait for the temperature to stabilise. Record the initial temperature in a table.
3. Using a measuring cylinder, measure 40 cm^3 of 1.00 $moldm^{-3}$ NaOH (sodium hydroxide). Measure the mass and temperature of the solution and record in a table.
4. Press collect on the data logger and the pour the 25cm^3 of 1.00 $moldm^{-3}$ NaOH into the insulated cup containing 25cm^3 of 1.00 $moldm^{-3}$ HCl
5. Collect the data for 180 seconds and record the maximum temperature reached.

Results:

Reactant	mass (±0.01g)	initial temperature (±0.2 ^oC)	maximum temperature (±0.2 ^oC)	change in temperature (±0.4 ^oC)
HCl				
NaOH				

Calculations:

1. Determine the limiting reactant in the reaction

2. Calculate the heat released using $Q=mc\Delta T$

3. Divide the heat released by the amount in mol of the limiting reactant.

Enthalpy change of neutralisation = ___________kJ mol^{-1}

Analysis:

1. What assumptions do we usually make when calculating enthalpy changes involving solutions? What assumptions did we make in this experiment?

2. The literature value for the enthalpy change of neutralisation is – 57.0 $kJmol^{-1}$. Calculate the % error using this literature value.

3. Suggest reasons why the experimental value is different to the literature value and suggest improvements to the experiment.

Topic 6.1 Investigation of rates of reaction experimentally and evaluation of results.

Title: Effect of concentration on the rate of reaction.

Background: Sodium thiosulfate solution and dilute hydrochloric acid are both clear, colourless liquids. They react together according to the equation below:

$$NaS_2O_{3(aq)} + 2HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + SO_{2(g)} + S_{(s)}$$

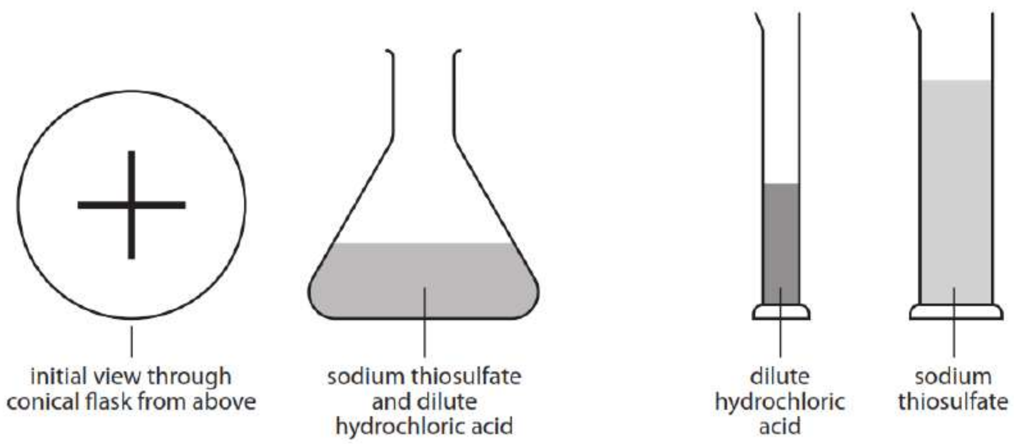
The sulfur produced makes the reaction mixture go cloudy. The faster the reaction, the faster the reaction mixture goes cloudy. You will investigate the effect of changing the concentration of sodium thiosulfate on the rate of reaction.

Materials:

0.100 $moldm^{-3}$ $Na_2S_2O_3$
1.00 $moldm^{-3}$ HCl
250 cm^3 conical flask
50 cm^3 measuring cylinder
10 cm^3 measuring cylinder
thermometer
stopwatch

Procedure:

1. Draw a dark cross on a piece of paper.
2. Place a conical flask on top of the cross.
3. Measure 10 cm^3 of 0.100 $moldm^{-3}$ $Na_2S_2O_3$ and pour it into the conical flask.
4. Measure 40 cm^3 of water and put it into the conical flask. Swirl the flask to mix the contents.
5. Measure 10 cm^3 of 1.00 mol dm^{-3} HCl. Pour the acid into the flask, start the stop watch, and swirl the flask.
6. Time how long it takes for the cross to disappear.
7. Wash out the flask thoroughly.
8. Repeat the experiment using the other volumes of sodium thiosulfate and water in the table below. Keep the volume and the concentration of acid the same each time.



Volume of 0.100 moldm^{-3} $Na_2S_2O_3$ (cm^3)	Volume of water (cm^3)	Concentration of $Na_2S_2O_3$ (mol dm^{-3})
50.0	0.00	
40.0	10.0	
30.0	20.0	
20.0	30.0	
10.0	40.0	

Calculations:

Results:

Concentration of $Na_2S_2O_3$ (mol dm^{-3})	Time taken for cross to disappear (s)				
	Trial 1	Trial 2	Trial 3	Average (s)	1/time s^{-1}

Analysis:

1) Plot a graph of concentration of $Na_2S_2O_3$ (x axis) against 1/time (y axis).

2) From your graph, describe and explain the effect of increasing the concentration of sodium thiosulfate on the rate of reaction.

Title: Iodine clock reaction

To investigate the reaction of iodate(V) ions with sulfate(IV) ions in acidic solution and to determine the order of the reaction with respect to hydrogen ions.

Background: The iodate(V) ion is an oxidising agent and reacts with sulfate(IV) ions in acidic solution to produce iodine in solution, according to the following equation:

Stage 1: $IO_3^- + 3SO_3^{2-} \rightarrow I^- + 3SO_4^{2-}$

Stage 2: $IO_3^- + 5I^- + 6H^+ \rightarrow 3H_2O + 3I_2$

Overall: $2IO_3^- + 5SO_3^{2-} + 2H^+ \rightarrow I_2 + 5SO_4^{2-} + H_2O$

Iodine is only liberated when acid is added. It is possible to determine the effect of acid on the initial rate of reaction by timing how long it takes for the iodine to be produced. This indicated by the formation of a blue colour with starch solution under different conditions of acid concentration, whilst keeping all other concentrations constant.

Apparatus:

300 cm^3 beaker

Two 100 cm^3 measuring cylinder

One 10 cm^3 measuring cylinder

Potassium iodate(V) solution (200 cm^3 3.50 g dm^{-3})

Sodium sulfate(IV) solution (200 cm^3 5.00 g dm^{-3})

0.100 mol dm^{-3} sulfuric acid (500 cm^3)

Starch solution (freshly prepared)

Stopwatch

Glass stirring rod

Procedure:

1. Measure 15 cm^3 of the potassium iodate(V) solution into a 100 cm^3 measuring cylinder and add 85 cm^3 of deionised water to dilute it to 100 cm^3.
2. Transfer this solution to a 400 cm^3 beaker and add 5 cm^3 of starch solution using a 10 cm^3 measuring cylinder.
3. In a second 100 cm^3 measuring cylinder, take 15 cm^3 of sodium sulfate(IV) solution and add 85 cm^3 of 0.100 mol dm^{-3} sulfuric acid.
4. Pour this solution into the 400 cm^3 beaker containing the potassium iodate(V) solution and start the stop watch simultaneously. Stir the contents of the beaker with the glass rod.
5. Record in a Table the time taken (*t* in seconds) for the blue colour to appear.
6. Repeat the experiment using the same volumes of potassium iodate(V) solution, starch solution and sodium sulfate(IV) solution, but vary the concentration of sulfuric acid by changing the volume of sulfuric acid and making the total volume of the acidified sodium sulfate(IV) solution up to 100 cm^3 by the addition of deionised water. The necessary volumes are shown in the table below with the initial experiment recorded on the right hand side of the Table.

Experiment	1	2	3	4	5	Initial
Acid volume (cm^3)	25	35	45	55	70	85
Water volume (cm^3)	60	50	40	30	15	0
$Na_2S_2O_3$ volume (cm^3)	15	15	15	15	15	15

Results:

Experiment	**Concentration of H_2SO_4 ($moldm^{-3}$)**	**Time taken for blue colour to appear (s)**
Initial		

1		
2		
3		
4		
5		

Topic 8.3 Students should be familiar with the use of a pH meter and universal indicator.

Title: Reactions of acids and bases

Experiment 1 – Comparing the reaction of magnesium with a weak and strong acid

- Cut four 1 cm pieces of Mg ribbon
- Fill two test tubes with approximately $10cm^3$ of 1.0 $moldm^{-3}$ CH_3COOH and 1.0 $moldm^{-3}$ HCl
- Add two pieces of Mg ribbon to each test tube.
- Place a boiling tube over the top of the test tube to collect the gas produced.

Reaction	Observations
CH_3COOH + Mg	
HCl + Mg	

Experiment 2 – Comparing conductivity of a weak and strong acid and base

- Fill four $100cm^3$ beakers with approximately 50 cm^3 of 1.0 $moldm^{-3}$ CH_3COOH, 1.0 $moldm^{-3}$ HCl, 50 cm^3 1.0 $moldm^{-3}$ NH_3 and 50 cm^3 1.0 $moldm^{-3}$ NaOH
- Set up an electrical circuit using graphite rods as electrodes.
- Switch on the power source and compare the brightness of the bulbs.

Electrolyte	Observations
1.0 $moldm^{-3}$ CH_3COOH	
1.0 $moldm^{-3}$ HCl	
1.0 $moldm^{-3}$ NH_3	

1.0 moldm^{-3} NaOH	

Experiment 3 – Comparing the pH of strong and weak acids and bases

- Use the same solutions as the previous experiment.
- Use a pH probe to test the pH of each of the solutions.
- Use pH paper to test the pH of each of the solutions.

Solution	pH with probe	pH with pH paper
1.0 moldm^{-3} CH_3COOH		
1.0 moldm^{-3} HCl		
1.0 moldm^{-3} NH_3		
1.0 moldm^{-3} NaOH		

Analysis:

Experiment 1

1) Write balanced chemical equations for the reactions of Mg with CH_3COOH and HCl.

2) Why does the strong acid react faster than the weak acid with Mg? (think about the factors that affect the rate of a reaction and the rate of formation of hydrogen gas).

3) Would you expect the same results if a weak and strong base were used? Explain your answer.

Experiment 2

4) What in the solutions allows the current to flow through?

5) Explain the difference in the brightness of the bulbs (why does a strong acid allow more current to flow through than a weak acid?).

Experiment 3

6) Explain the difference in pH between the strong and weak acids and bases.

7) Explain the difference between the strength and concentration of acids and bases.

19.1 Perform lab experiments which could include single replacement reactions in aqueous solutions.

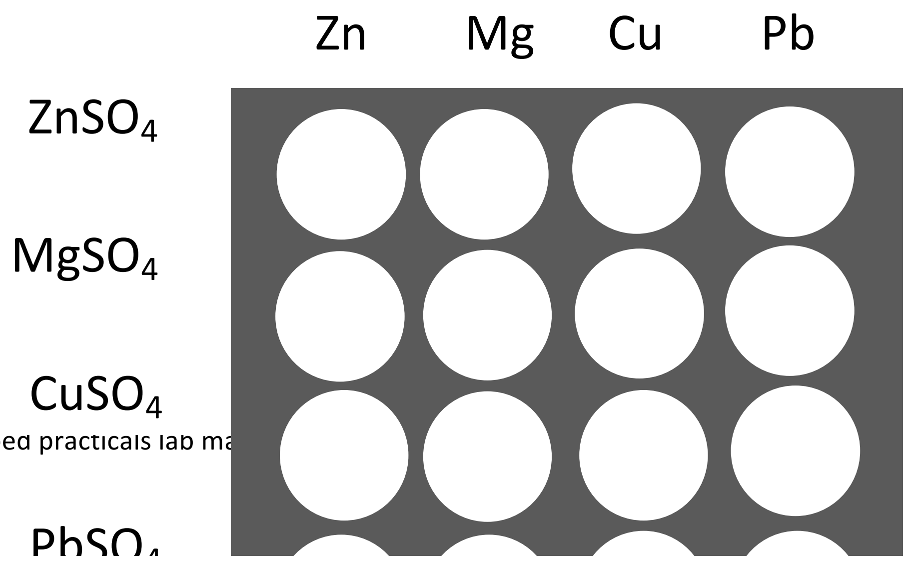
Title: Displacement reactions

Background: Some metals are more reactive than others. The activity series lists metals in order of their reactivity (or strength as reducing agents). More reactive metals are at the top (stronger reducing agents) and less reactive metals are at the bottom (weaker reducing agents). In a displacement reaction, a more reactive metal displaces the ions of a less reactive metal from solution. In this experiment, you will react four metals with the salts of their ions.

The metals are zinc (Zn), lead (Pb), copper (Cu) and aluminium (Al). The metal salts are zinc sulfate, copper sulfate, lead sulfate and magnesium sulfate (all with a concentration of 0.100 $moldm^{-3}$).

Procedure:

1. Add a few drops of each metal salt to the spotting tile as shown below.
2. Add a piece of each metal to the metals salts in the spotting tile.
3. Record your observations in the table below.



Results:

	Zn	**Mg**	**Cu**	**Pb**
$ZnSO_4$				
$MgSO_4$				
$CuSO_4$				
$PbSO_4$				

Analysis:

1) Arrange the metals in order of reactivity (from most reactive to least reactive). Explain your reasoning.

2) Arrange the metals in order of the strength as reducing agents (from strongest to weakest).

3) Write net ionic equations for the reactions that occurred.

9.2 Performance of laboratory experiments involving a typical voltaic cell using two metal/metal–ion half-cells.

Title: Construct a voltaic cell

Background: A voltaic cell is prepared from two half-cells connected together by a salt-bridge. A spontaneous reaction produces an electrical potential (voltage). A voltaic cell is constructed by using two metal electrodes in solutions of their respective salts (the electrolyte component of the cell) with known molar concentrations. In this experiment, you will use a voltmeter to measure the potential of a voltaic cell made with copper and zinc half-cells.

Procedure:

1. Use two 50 cm^3 beakers to make the half cells.
2. Measure 20 cm^3 of 0.10 mol dm^{-3} $Cu(NO_3)_2$ and 20 cm^3 of 0.10 mol dm^{-3} $Zn(NO_3)_2$ in two 50 cm^3 beakers.
3. Polish one Cu and one Zn metal strip for the electrodes.
4. Place the Cu strip in the beaker of $Cu(NO_3)_2$ solution and place the Zn strip in the beaker of $Zn(NO_3)_2$ solution. These are the half cells of your Cu-Zn voltaic cell.
5. Make a salt bridge by soaking a strip of filter paper in a beaker than contains a small amount of 1.00 mol dm^{-3} KNO_3 solution.
6. Connect the Cu and Pb half cells with the salt bridge.
7. Connect the wires to the electrodes and use a voltmeter to measure the potential of the Cu-Zn voltaic cell.

Analysis:

1) Draw a diagram of the voltaic cell below. Show the direction of electron flow.

2) Write half equations that occur at the anode and cathode.

10.1 Construction of 3D models (real or virtual) of organic molecules.

Diploma Programme

Design technology guide

First assessment 2016

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Diploma Programme

Design technology guide

First assessment 2016

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Diploma Programme
Design technology guide

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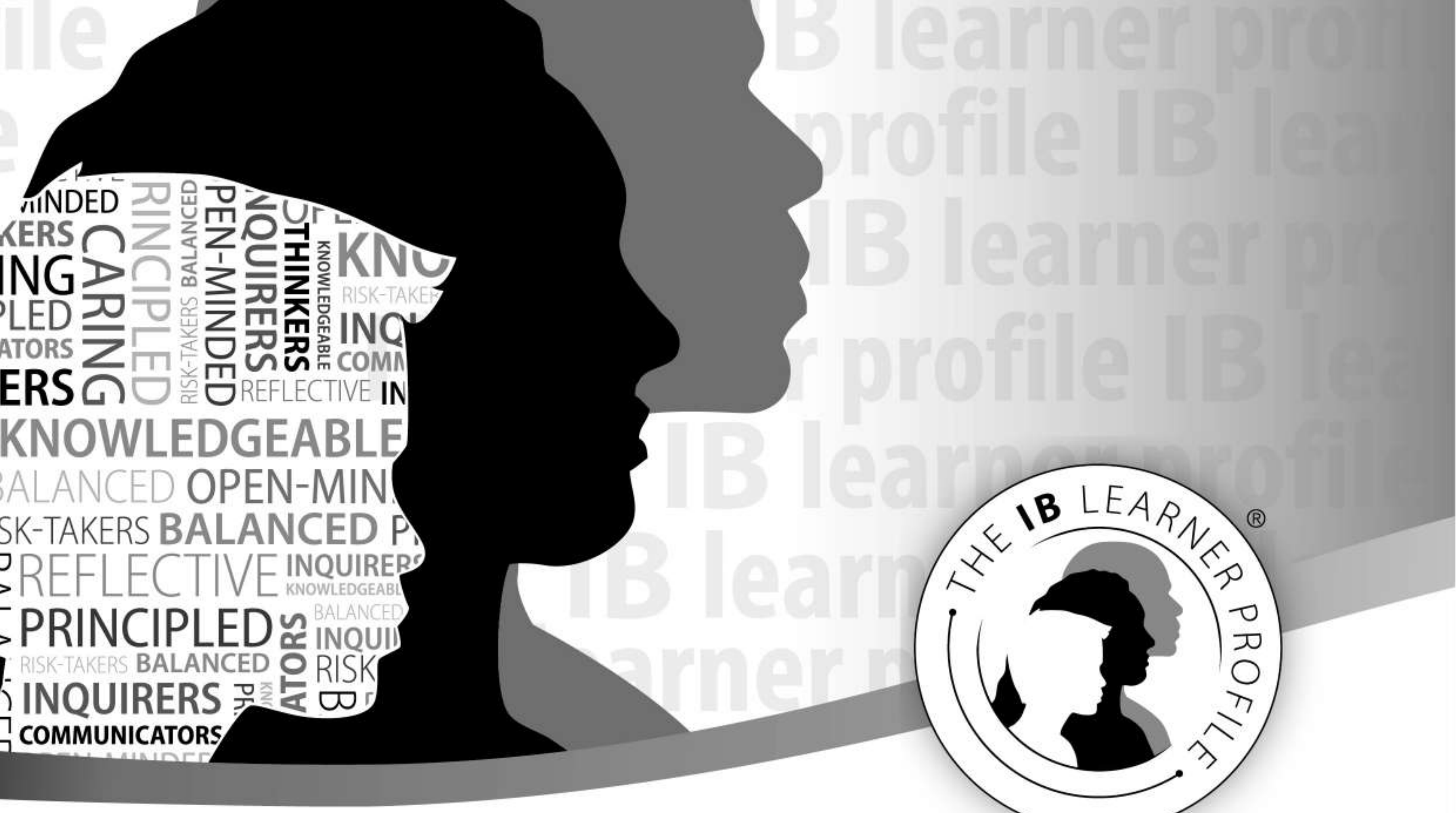
IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.



IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

As IB learners we strive to be:

INQUIRERS
We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life.

KNOWLEDGEABLE
We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance.

THINKERS
We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions.

COMMUNICATORS
We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups.

PRINCIPLED
We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences.

OPEN-MINDED
We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.

CARING
We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.

RISK-TAKERS
We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change.

BALANCED
We understand the importance of balancing different aspects of our lives—intellectual, physical, and emotional—to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live.

REFLECTIVE
We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.

The IB learner profile represents 10 attributes valued by IB World Schools. We believe these attributes, and others like them, can help individuals and groups become responsible members of local, national and global communities.

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Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This guide can be found on the subject page of the online curriculum centre (OCC) at http://occ.ibo.org, a password-protected IB website designed to support IB teachers. It can also be purchased from the IB store at http://store.ibo.org.

Additional resources

Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the OCC. Past examination papers as well as markschemes can be purchased from the IB store.

Teachers are encouraged to check the OCC for additional resources created or used by other teachers. Teachers can provide details of useful resources, for example: websites, books, videos, journals or teaching ideas.

Acknowledgment

The IB wishes to thank the educators and associated schools for generously contributing time and resources to the production of this guide.

First assessment 2016

The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme model

The course is presented as six academic areas enclosing a central core (see figure 1). It encourages the concurrent study of a broad range of academic areas. Students study two modern languages (or a modern language and a classical language); a humanities or social science subject; a science; mathematics; and one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.

Figure 1

Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can, instead of an arts subject, choose two subjects from another area. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers.

The core of the Diploma Programme model

All Diploma Programme students participate in the three course elements that make up the core of the model.

Theory of knowledge (TOK) is a course that is fundamentally about critical thinking and inquiry into the process of knowing rather than about learning a specific body of knowledge. The TOK course examines the nature of knowledge and how we know what we claim to know. It does this by encouraging students to analyse knowledge claims and explore questions about the construction of knowledge. The task of TOK is to emphasize connections between areas of shared knowledge and link them to personal knowledge in such a way that an individual becomes more aware of his or her own perspectives and how they might differ from others.

Creativity, activity, service (CAS) is at the heart of the Diploma Programme. The emphasis in CAS is on helping students to develop their own identities, in accordance with the ethical principles embodied in the IB mission statement and the IB learner profile. It involves students in a range of activities alongside their academic studies throughout the Diploma Programme. The three strands of CAS are creativity (arts and other experiences that involve creative thinking), activity (physical exertion contributing to a healthy lifestyle) and service (an unpaid and voluntary exchange that has a learning benefit for the student). Possibly, more than any other component in the Diploma Programme, CAS contributes to the IB's mission to create a better and more peaceful world through intercultural understanding and respect.

The extended essay, including the world studies extended essay, offers the opportunity for IB students to investigate a topic of special interest, in the form of a 4,000-word piece of independent research. The area of research undertaken is chosen from one of the students' Diploma Programme subjects, or in the case of the interdisciplinary world studies essay, two subjects, and acquaints them with the independent research and writing skills expected at university. This leads to a major piece of formally presented, structured writing, in which ideas and findings are communicated in a reasoned and coherent manner, appropriate to the subject or subjects chosen. It is intended to promote high-level research and writing skills, intellectual discovery and creativity. As an authentic learning experience it provides students with an opportunity to engage in personal research on a topic of choice, under the guidance of a supervisor.

Approaches to teaching and approaches to learning

Approaches to teaching and learning across the Diploma Programme refer to deliberate strategies, skills and attitudes which permeate the teaching and learning environment. These approaches and tools, intrinsically linked with the learner profile attributes, enhance student learning and assist student preparation for the Diploma Programme assessment and beyond. The aims of approaches to teaching and learning in the Diploma Programme are to:

- empower teachers as teachers of learners as well as teachers of content
- empower teachers to create clearer strategies for facilitating learning experiences in which students are more meaningfully engaged in structured inquiry and greater critical and creative thinking
- promote both the aims of individual subjects (making them more than course aspirations) and linking previously isolated knowledge (concurrency of learning)
- encourage students to develop an explicit variety of skills that will equip them to continue to be actively engaged in learning after they leave school, and to help them not only obtain university admission through better grades but also prepare for success during tertiary education and beyond
- enhance further the coherence and relevance of the students' Diploma Programme experience
- allow schools to identify the distinctive nature of an IB Diploma Programme education, with its blend of idealism and practicality.

The five approaches to learning (developing thinking skills, social skills, communication skills, self-management skills and research skills) along with the six approaches to teaching (teaching that is inquiry-based, conceptually focused, contextualized, collaborative, differentiated and informed by assessment) encompass the key values and principles that underpin IB pedagogy.

The IB mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IB, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

Academic honesty

Academic honesty in the Diploma Programme is a set of values and behaviours informed by the attributes of the learner profile. In teaching, learning and assessment, academic honesty serves to promote personal integrity, engender respect for the integrity of others and their work, and ensure that all students have an equal opportunity to demonstrate the knowledge and skills they acquire during their studies.

All coursework—including work submitted for assessment—is to be authentic, based on the student's individual and original ideas with the ideas and work of others fully acknowledged. Assessment tasks that require teachers to provide guidance to students or that require students to work collaboratively must be completed in full compliance with the detailed guidelines provided by the IB for the relevant subjects.

For further information on academic honesty in the IB and the Diploma Programme, please consult the IB publications *Academic honesty* (2011), *The Diploma Programme: From principles into practice* (2009) and *General regulations: Diploma Programme* (2011). Specific information regarding academic honesty as it pertains to external and internal assessment components of this Diploma Programme subject can be found in this guide.

Acknowledging the ideas or work of another person

Coordinators and teachers are reminded that candidates must acknowledge all sources used in work submitted for assessment. The following is intended as a clarification of this requirement.

Diploma Programme candidates submit work for assessment in a variety of media that may include audio-visual material, text, graphs, images and/or data published in print or electronic sources. If a candidate uses the work or ideas of another person, the candidate must acknowledge the source using a standard style of referencing in a consistent manner. A candidate's failure to acknowledge a source will be investigated by the IB as a potential breach of regulations that may result in a penalty imposed by the IB final award committee.

The IB does not prescribe which style(s) of referencing or in-text citation should be used by candidates; this is left to the discretion of appropriate faculty/staff in the candidate's school. The wide range of subjects, three response languages and the diversity of referencing styles make it impractical and restrictive to insist on particular styles. In practice, certain styles may prove most commonly used, but schools are free to choose a style that is appropriate for the subject concerned and the language in which candidates' work is written. Regardless of the reference style adopted by the school for a given subject, it is expected that the minimum information given includes: name of author, date of publication, title of source, and page numbers as applicable.

Candidates are expected to use a standard style and use it consistently so that credit is given to all sources used, including sources that have been paraphrased or summarized. When writing text, candidates must clearly distinguish between their words and those of others by the use of quotation marks (or other method, such as indentation) followed by an appropriate citation that denotes an entry in the bibliography. If an electronic source is cited, the date of access must be indicated. Candidates are not expected to show faultless expertise in referencing, but are expected to demonstrate that all sources have been acknowledged. Candidates must be advised that audio-visual material, text, graphs, images and/or data published in print or in electronic sources that is not their own must also attribute the source. Again, an appropriate style of referencing/citation must be used.

Learning diversity and learning support requirements

Schools must ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity in the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes*.

Nature of design

1. What is design?

1.1 Design is a process that links innovation and creativity.

1.2 Design provides a structured process based on well-established design principles to resolve authentic problems.

1.3 Design involves generating ideas, exploring the possibilities and constraints to find solutions.

1.4 Design is a cyclical and iterative process.

1.5 Design is human-centred and focuses on the needs, wants and limitations of the end user.

1.6 Competent design can be achieved by all and is not restricted to uniquely skilled individuals. The use of well-established design principles and processes increases the probability that a design will be successful.

1.7 Designers use a wide variety of concepts, principles and strategies, which, taken together, make up what is known as design methodology. Designers adapt their approach to different design contexts, but they have a common understanding of the process necessary to form valid and suitable solutions.

1.8 Competent design requires imagination and creativity together with substantial factual, procedural and conceptual knowledge.

1.9 In-depth investigation of the nature of a problem is required to establish clear parameters for a design specification. This determines the scope of a solution and is necessary for good decision-making.

1.10 Designers must adopt an approach that allows them to think creatively within the constraints of a design specification. The ability to create unique and original solutions to a proposed problem is advantageous.

1.11 Designers need to critically explore the latest advances in technology to determine whether they can be used to develop the best solution to a problem. Traditional methods can be more appropriate and user-friendly.

1.12 Design is a collaborative endeavour requiring diverse teams of experts to realize a tangible solution.

1.13 Modelling is central to design. This involves cognitive, graphical, physical, aesthetic, mechanical, and digital modelling.

1.14 The growth in computing power has made modelling much more powerful. The generation of digital prototypes allows dynamic modelling of complex situations. Simulations involving large amounts of data, large numbers of variables and complex calculations speed up the design process and extend possible solutions.

1.15 A designer should maintain an unbiased view of a situation and evaluate a context objectively, highlighting the strengths, weaknesses and opportunities of a product, service or system.

1.16 Designers have a responsibility to the community and the environment. Their decisions often have major impact on both and they must always be aware of the ethical and moral dimensions of their work.

1.17 Design is carried out by a community of people from a wide variety of backgrounds and traditions, and this has clearly influenced the way design has progressed at different times. However, it is important to understand that design is universal and has common understandings, methodologies, and goals.

1.18 Designers must consider how users will interact with, use and misuse the products they design.

1.19 Designers should be aware that with the advancement of technology, there are now issues surrounding security and safety of personal data that need to be addressed in the majority of contexts.

1.20 Design permeates every aspect of human experience. Individuals make design decisions in all areas of their work, home and leisure.

2. The role of science and technology in design

2.1 Both science and technology have a fundamental relationship with design. Technology preceded science, but now most technological developments are based on scientific understanding.

2.2 Traditional technology comprised useful artifacts often with little understanding of the science underpinning their production and use. In contrast, modern technology involves the application of scientific discoveries to produce useful artifacts.

2.3 The application of scientific discovery to solve a problem enables designers to create new technologies.

2.4 These new technologies can be utilized by scientists to make new scientific discoveries.

2.5 Designers use new and existing technologies to create new products, services and systems.

2.6 The rapid pace of scientific discovery has impacted the rate that designers can develop new technologies. New technologies allow new products to be developed, which solve long-standing problems, improve on existing solutions and fill gaps in markets.

2.7 Often, by solving one problem and designing new technologies, there are unforeseen consequences, which bring new problems.

2.8 Technology is designed in response to changes in human needs. Many societies have benefited from the design of technologies to provide resources, such as electricity and fresh water supplies, clothing, food and transport.

2.9 The technologies that sustain the digital revolution are only one facet of technology. Design remains involved in developing technology to satisfy basic human needs and make people's lives easier.

2.10 The concept of sustainability is becoming a greater priority for designers. The development of sustainable technologies is a response to environmental and social pressures relating to climate change, energy and resource depletion.

3. Characteristics of a good designer

The following characteristics frame a profile of both professional and aspiring designers. They reflect the desirable abilities, skill sets and mindset of all designers.

Designers can/are able to:

3.1 problem solve/troubleshoot in any context or situation, across a variety of design disciplines

3.2 realize innovative products, services, systems and technologies by learning through failure, extensive trialling, constant evaluation and redevelopment, perseverance and determination

3.3 seek, establish and verify broad concepts and general principles that underlie design methodology

3.4 conduct thorough research, synthesize evidence and apply the findings to the development of innovative products, services, systems and technologies

3.5 carefully observe human interactions and situations, identify and monitor short- and long-term trends and ask pertinent questions to explore design opportunities

3.6 assess the risks associated with the design and use of technology as well as any associated moral, social, ethical or environmental issues

3.7 think creatively and develop ideas beyond the confines of existing concepts, principles and modes of thinking

3.8 empathize with individuals or groups to ascertain and identify needs or design opportunities

3.9 collaborate, inspire and enthuse through effective communication using a variety of appropriate modes and media

3.10 appreciate the influence of others within the field of design including historical and current leaders, movements and organizations.

Nature of design technology

Design, and the resultant development of new technologies, has given rise to profound changes in society: transforming how we access and process information; how we adapt our environment; how we communicate with others; how we are able to solve problems; how we work and live.

Technology emerged before science, and materials were used to produce useful and decorative artifacts long before there was an understanding of why materials had different properties that could be used for different purposes. In the modern world the reverse is the case, and designers need to have an understanding of the possibilities offered by science to realize the full potential of what they can design in terms of new technologies, products and systems.

Design is the link between innovation and creativity, taking thoughts and exploring the possibilities and constraints associated with products or systems, allowing them to redefine and manage the generation of further thought through prototyping, experimentation and adaptation. It is human-centred and focuses on the needs, wants and limitations of the end user.

Competent design is within the reach of all. Through the practice and application of well-established design principles and methodologies, individuals can increase the likelihood that a design will be successful. These principles taken together make up what is known as the design cycle.

Designing requires an individual to be imaginative and creative, while having a substantial knowledge base of important factors that will aid or constrain the process. Decision-making needs to be supported by adequate and appropriate research and investigation. Designers must think “out of the box” to develop innovative solutions, while thinking “in the box” to conform to requirements set by clients or research.

Both the ideas of design and the process of design can only occur in a human context. Design involves multidisciplinary teams and stakeholders with different backgrounds and traditions. It is important to understand, however, that to design is to be involved in a community of inquiry with certain common beliefs, methodologies, understandings and processes. Design is multidisciplinary and draws from many areas including the natural and social sciences, mathematics and arts.

Diploma Programme design technology aims to develop internationally minded people whose enhanced understanding of design and the technological world can facilitate our shared guardianship of the planet and create a better world.

It focuses on analysis, design development, synthesis and evaluation. The creative tension between theory and practice is what characterizes design technology within the Diploma Programme sciences group.

Inquiry and problem-solving are at the heart of the subject. Diploma Programme design technology requires the use of the design cycle as a tool, which provides the methodology used to structure the inquiry and analysis of problems, the development of feasible solutions, and the testing and evaluation of the solution. In Diploma Programme design technology, a solution can be defined as a model, prototype, product or system that students have developed independently.

Diploma Programme design technology achieves a high level of design literacy by enabling students to develop critical-thinking and design skills, which they can apply in a practical context. While designing may take various forms, it will involve the selective application of knowledge within an ethical framework.

A well-planned design programme enables students to develop not only practical skills but also strategies for creative and critical thinking.

The design cycle

Each and every designer approaches a problem in a different way. Depending on the designers' specialism, they tend to have their own methodology, but there are some general activities common to all designers. The design cycle model is a fundamental concept underpinning the design process and central to a student's understanding of design activities.

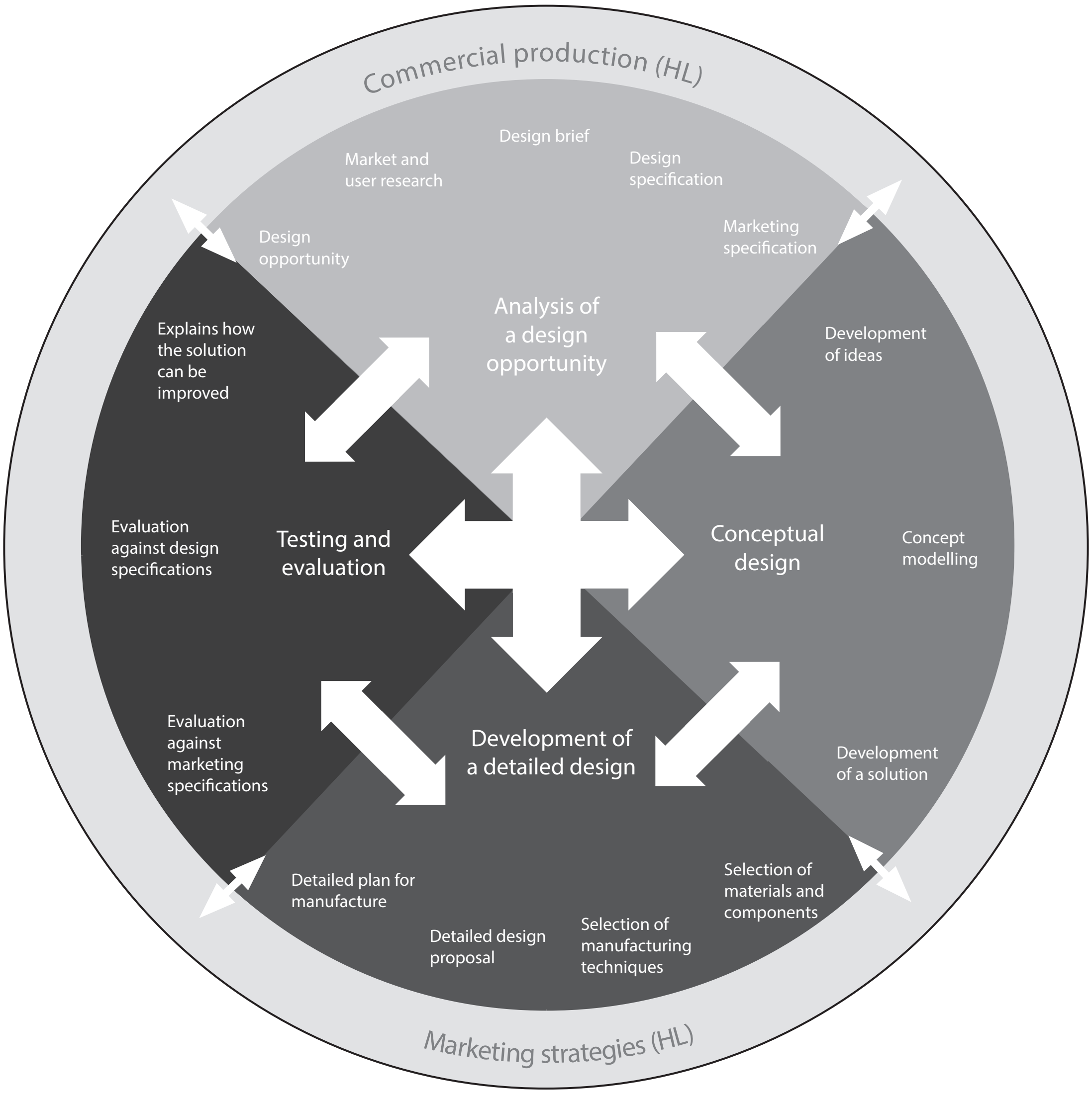


Figure 2

The Diploma Programme design cycle

The design cycle diagram (figure 2) represents the Diploma Programme design technology methodology of how designers develop products. The process is divided into the following four stages.

- Analysis of a design opportunity
- Conceptual design
- Development of a detailed design
- Testing and evaluation

This incremental process allows the designer to go from identifying a design opportunity to the testing and evaluation of a solution. This process leads to invention.

At higher level (HL), the following two additional stages are added.

- Commercial production
- Marketing strategies

The student must take his or her invention and plan to develop it into an innovation, that is get the product to diffuse into the marketplace. The two new stages are designed to extend the students' skills and ability to create innovations.

Design technology and the international dimension

Technology itself is an international endeavour; the exchange of information and ideas around the world has been both a cause and an effect of the development of technology. This exchange is not a new phenomenon but it has accelerated in recent times with the development of information and communication technologies. Indeed, the idea that technology is a modern invention is a myth—people began developing technologies when they first started fashioning tools from stones, making fire to process their food, and shaping material to keep themselves warm. Teachers are encouraged to emphasize this contribution in their teaching of various topics, perhaps through an analysis of the principles of early technologies and the use of timeline websites. The design technology method in its widest sense, with its emphasis on creativity, innovation, open-mindedness and freedom of thought, transcends politics, religion and nationality. Where appropriate within certain topics, the syllabus details sections in the group 4 guides contain links illustrating the international aspects of technology.

On an organizational level, many international bodies now exist to analyse and promote technology. International bodies such as the International Labour Organization, the United Nations Industrial Development Organization, the United Nations Framework Convention on Climate Change, the United Nations Conference on Trade and Development and many others monitor, plan and provide information about global technology issues. The rapid profusion of these international organizations attests to the global nature of technology: both the internationalization of the design and development of technology, and the global effects of technologies, for example, climate change. Students are encouraged to access the extensive websites of these international organizations to enhance their appreciation of the international dimensions of technology.

Some topics in the guide are specifically written to bring out this global dimension. On a practical level, the group 4 project mirrors real design methodology by encouraging collaboration between schools across the regions.

The power of technology to transform societies is unparalleled. It has the potential to produce great universal benefits or to reinforce inequalities and cause harm to people and the environment. In line with the IB mission statement, students need to be aware of the moral responsibility of designers to ensure that appropriate technologies are available to all communities on an equitable basis and that they have the technological capacity to use this for developing sustainable societies.

Students' attention should be drawn to sections of the syllabus with links to international-mindedness. Examples of issues relating to international-mindedness are given within sub-topics in the syllabus content.

Distinction between SL and HL

Design technology students at standard level (SL) and higher level (HL) undertake a common core and have four common assessment criteria used for their internal assessment (IA). They are presented with a syllabus that encourages the development of certain skills, attributes and attitudes, as described in the "Assessment objectives" section of this guide.

While the skills and activities of design technology are common to students at both SL and HL, students at HL are required to study additional topics and are required to meet two additional assessment criteria for internal assessment. The distinction between SL and HL is one of breadth and depth.

Prior learning

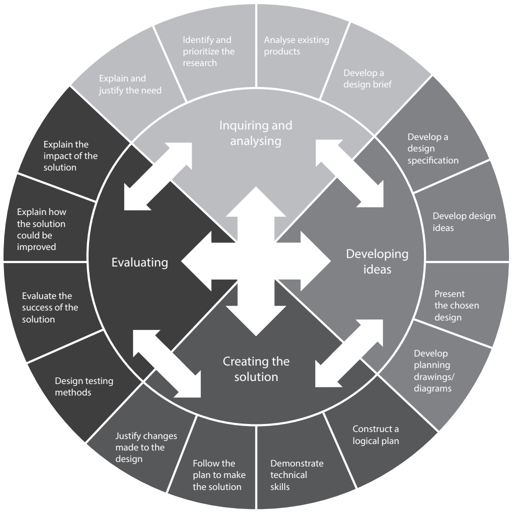
Past experience shows that students will be able to study design technology at SL successfully with no background in, or previous knowledge of, the subject. Their approach to study, characterized by the specific IB learner profile attributes—inquirers, thinkers and communicators—will be significant here.

However, for most students considering the study of design technology at HL some previous exposure to design would be beneficial. Specific topic details are not specified but students who have undertaken the IB Middle Years Programme (MYP) would be well prepared. Other national design technology education qualifications or a school-based design technology course would also be suitable preparation for study of design technology at HL.

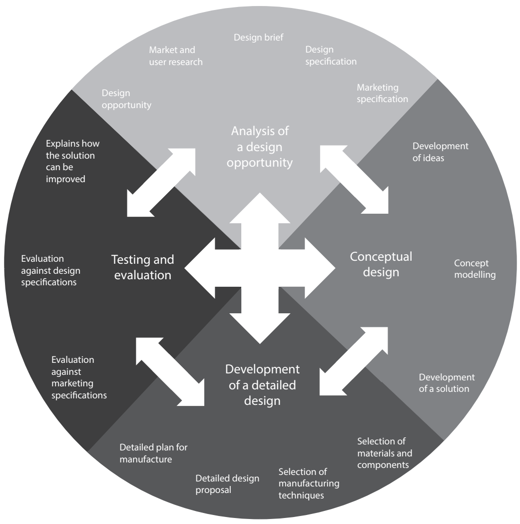
Links to the Middle Years Programme

Diploma Programme design technology builds on experiences of inquiry that students have gained in their time in the IB Primary Years Programme (PYP) and MYP. PYP teaching and learning experiences challenge students to be curious, ask questions, explore and interact with the environment physically, socially and intellectually to construct meaning and refine their understanding. Even when there is no design component in the PYP, the use of structured inquiry is a precursor to the problem-solving and inquiry-based approach of MYP design.

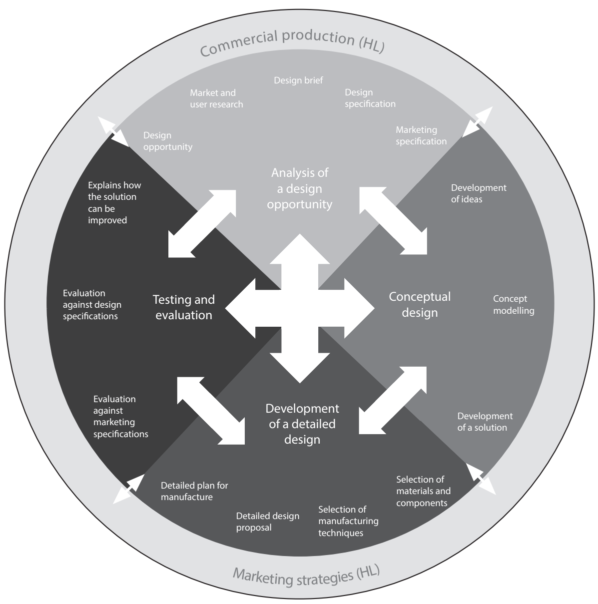
The inquiry-based approach of MYP design courses thoroughly prepare students for Diploma Programme design technology. The MYP design objectives and assessment criteria provide a clear and smooth transition from the MYP to Diploma Programme. The alignment between the design methodology expressed through the MYP design cycle is further developed in Diploma Programme design technology with problem-solving through invention at the heart of SL; and this is further extended towards innovation at HL. As such, students continuing on to Diploma Programme design technology from MYP have gained a wealth of experience using the MYP design cycle and will have developed critical-thinking and design skills, which they will be able to apply to solve more complex problems.



MYP design cycle



DP design cycle (SL)



DP design cycle (HL)

Design technology and theory of knowledge

The theory of knowledge (TOK) course (first assessment 2015) engages students in reflection on the nature of knowledge and on how we know what we claim to know. The course identifies eight ways of knowing: reason, emotion, language, sense perception, intuition, imagination, faith and memory. Students explore these means of producing knowledge within the context of various areas of knowledge: the natural sciences, the social sciences, the arts, ethics, history, mathematics, religious knowledge systems and indigenous knowledge systems. The course also requires students to make comparisons between the different areas of knowledge; reflecting on how knowledge is arrived at in the various disciplines, what the disciplines have in common, and the differences between them.

TOK lessons can support students in their study of design technology, just as the study of design technology can support students in their TOK course. TOK provides a space for students to engage in stimulating wider discussions about questions such as the extent to which technology is both an enabler and limiter of knowledge. It also provides an opportunity for students to reflect on the methodologies of design technology, and how these compare to the methodologies of other areas of knowledge.

In this way there are rich opportunities for students to make links between their design technology and TOK courses. One way in which design technology teachers can help students to make these links to TOK is by drawing students' attention to knowledge questions which arise from their subject content. Knowledge questions are open-ended questions about knowledge, and include questions such as:

- How does knowledge in design technology progress? How does that compare to how knowledge progresses in other areas of knowledge?
- Are intuitively appealing explanations more likely to be true than explanations supported by other means?
- What is the role of imagination in design technology?
- Are the methods used in design technology closer to the methods used in the arts or the methods used in the natural sciences?
- What is the relationship between facts/data and theories, and how does this differ in different areas of knowledge?
- What is the impact of culture in the production and distribution of knowledge in various areas of knowledge?
- To what extent does the methodology of an investigation limit or determine the possible outcomes?

Suggestions for TOK discussions and examples of relevant knowledge questions are provided throughout this guide, within the sub-topics in the syllabus content. Teachers can also find suggestions of interesting knowledge questions for discussion in the "Areas of knowledge" and "Knowledge frameworks" sections of the *Theory of knowledge guide*. Students should be encouraged to raise and discuss such knowledge questions in both their design technology and TOK classes.

Aims

Design technology aims

Through studying design technology, students should become aware of how designers work and communicate with each other. While the design methodology may take on a wide variety of forms, it is the emphasis on a practical approach through design work that characterizes this subject.

The aims of the subject state in a general way what the teacher may expect to teach or do, and what a student may expect to experience or learn.

The aims enable students, through the overarching theme of the nature of design, to develop:

1. a sense of curiosity as they acquire the skills necessary for independent and lifelong learning and action through inquiry into the technological world around them
2. an ability to explore concepts, ideas and issues with personal, local and global significance to acquire in-depth knowledge and understanding of design and technology
3. initiative in applying thinking skills critically and creatively to identify and resolve complex social and technological problems through reasoned ethical decision-making
4. an ability to understand and express ideas confidently and creatively using a variety of communication techniques through collaboration with others
5. a propensity to act with integrity and honesty, and take responsibility for their own actions in designing technological solutions to problems
6. an understanding and appreciation of cultures in terms of global technological development, seeking and evaluating a range of perspectives
7. a willingness to approach unfamiliar situations in an informed manner and explore new roles, ideas and strategies so they can articulate and defend their proposals with confidence
8. an understanding of the contribution of design and technology to the promotion of intellectual, physical and emotional balance and the achievement of personal and social well-being
9. empathy, compassion and respect for the needs and feelings of others in order to make a positive difference to the lives of others and to the environment
10. skills that enable them to reflect on the impacts of design and technology on society and the environment in order to develop their own learning and enhance solutions to technological problems.

Assessment objectives

The assessment objectives for design technology reflect those parts of the aims that will be formally assessed either internally or externally. Wherever appropriate, the assessment will draw upon environmental and technological contexts and identify the social, moral and economic effects of technology.

It is the intention of the design technology course that students are able to fulfill the following assessment objectives.

1. Demonstrate knowledge and understanding of:
    a. facts, concepts, principles and terminology
    b. design methodology and technology
    c. methods of communicating and presenting technological information.
2. Apply and use:
    a. facts, concepts, principles and terminology
    b. design methodology and technology
    c. methods of communicating and presenting technological information.
3. Construct, analyse and evaluate:
    a. design briefs, problems, specifications and plans
    b. methods, techniques and products
    c. data, information and technological explanations.
4. Demonstrate the appropriate research, experimentation, modelling and personal skills necessary to carry out innovative, insightful, ethical and effective designing.

Syllabus outline

Syllabus component	Teaching hours	
	SL	HL
Core	**90**	
1. Human factors and ergonomics	12	
2. Resource management and sustainable production	22	
3. Modelling	12	
4. Final production	23	
5. Innovation and design	13	
6. Classic design	8	
Additional higher level (AHL)		**54**
7. User-centred design (UCD)		12
8. Sustainability		14
9. Innovation and markets		13
10. Commercial production		15
Practical work	**60**	**96**
Design project	40	60
Group 4 project	10	10
Teacher-directed activities	10	26
Total teaching hours	**150**	**240**

The recommended teaching time is 240 hours to complete HL courses and 150 hours to complete SL courses as stated in the document *General regulations: Diploma Programme* (2011) (page 4 article 8.2).

Approaches to the teaching of design technology

Format of the syllabus

The format of the syllabus section of the group 4 guides gives prominence and focus to the teaching and learning aspects.

Topics

Topics are numbered for ease of reference (for example, "Topic 2: Resource management and sustainable production").

Sub-topics

Sub-topics are numbered as follows, "2.1 Resources and reserves". Further information and guidance about possible teaching times are contained in the teacher support material.

Each sub-topic begins with an essential idea. The essential idea is an enduring interpretation that is considered part of the general understanding of design.

Below the essential idea the sub-topic is presented in three columns.

The first column is the "Nature of design". This gives specific examples in context illustrating some aspects of the nature of design. These are linked directly to specific references in the "Nature of design" section of the guide to support teachers in their understanding of the general theme to be addressed.

The second column lists concepts and principles, which are the main general ideas to be taught, and "Guidance" gives information about the limits and constraints and the depth of treatment required.

The third column gives suggestions to teachers about relevant references to international-mindedness. It also gives examples of TOK knowledge questions (see *Theory of knowledge guide* published 2013) that can be used to focus students' thoughts on the preparation of the TOK prescribed essay. The "Utilization" section may link the sub-topic to other parts of the subject syllabus and other Diploma Programme subject guides. Finally, the "Aims" section refers to how design technology aims are being addressed in the sub-topic.

Format of the guide

Topic 1: <Title>

Essential idea: This lists the essential idea for each sub-topic.

1.1 Sub-topic		
Nature of design: This section relates the sub-topic to the overarching theme of nature of design.	**Concepts and principles:** • This section will provide specifics of the content requirements for each sub-topic. **Guidance:** • This section will provide constraints to the requirements for the concepts and principles.	**International-mindedness:** • Ideas that teachers can easily integrate into the delivery of their lessons. **Theory of knowledge:** • Examples of TOK knowledge questions. **Utilization:** (including syllabus and cross-curricular links) • Links to other topics within the *Design technology guide* and to other Diploma Programme courses. **Aims:** • Links to the design technology aims.

Design technology practical skills

> I hear and I forget. I see and I remember. I do and I understand.
>
> Confucius

Integral to the experience of students in any of the group 4 courses is their experience in the classroom, workshop, laboratory or in the field. Practical activities allow students to interact directly with natural materials, and primary and secondary data sources. These experiences provide the students with the opportunity to design investigations, collect data, develop manipulative skills, analyse results, collaborate with peers and evaluate and communicate their findings. Practical activities can be used to introduce a topic, investigate a phenomenon or allow students to consider and examine questions and curiosities.

By providing students with the opportunity for hands-on experimentation, they are carrying out some of the same processes that designers undertake.

It is important that students are involved in an inquiry-based practical programme that allows for the development of design thinking. It is not enough for students just to be able follow directions and to simply replicate a given procedure, they must be provided with the opportunities for genuine inquiry. Developing inquiry skills will give students the ability to construct an explanation based on reliable evidence and logical reasoning. Once developed, these higher-order thinking skills will enable students to be lifelong learners and design literate.

A school's practical scheme of work should allow students to experience the full breadth and depth of the course. This practical scheme of work must also prepare students to undertake the design project that is required for the internal assessment. The development of students' manipulative skills should involve them being able to follow instructions accurately and demonstrate the safe, competent and methodical use of a range of techniques and equipment, which can then be applied to a range of design contexts.

Mathematical requirements

All Diploma Programme design technology students should be able to:

- perform the basic arithmetic functions: addition, subtraction, multiplication and division
- carry out calculations involving means, decimals, fractions, percentages, ratios, approximations and reciprocals
- use standard notation (for example, 3.6×10^6)
- use direct and inverse proportion
- solve simple algebraic equations
- plot and interpret graphs (with suitable scales and axes) including two variables that show linear and non-linear relationships
- interpret graphs, including the significance of gradients, changes in gradients, intercepts and areas
- interpret data presented in various forms (for example, bar charts, histograms and pie charts).

Use of information and communication technology

Information and communication technology (ICT) involves the use of computers, its applications and communication facilities in teaching and learning activities. Therefore, the use of ICT goes beyond Diploma Programme design technology and extends to all the teaching and learning in all subjects across the curriculum. The effective use of ICT is included in approaches to learning (ATL) and, as such, schools must ensure that a whole-school approach is in place to allow students to develop information and technological literacy and become competent users of information and communication technologies such as computers and computer numerical control (CNC) machinery.

Depending upon the school resources, ICT should be used whenever appropriate:

- as a means of expanding students' knowledge of the world in which they live
- as a channel for developing concepts and skills
- as a powerful communication tool.

Planning your course

The syllabus as provided in the subject guide is not intended to be a teaching order. Instead it provides detail of what must be covered by the end of the course. A school should develop a scheme of work that best works for their students. For example, the scheme of work could be developed to match available resources, to take into account student prior learning and experience, or in conjunction with other local requirements.

HL teachers may choose to teach the core and AHL topics at the same time or teach them in a spiral fashion, by teaching the core topics in year one of the course and revisiting the core topics through the delivery of the AHL topics in year two of the course.

However the course is planned, adequate time must be provided for examination revision. Time must also be given for students to reflect on their learning experience and their growth as learners.

The IB learner profile

The design technology course is closely linked to the IB learner profile. By following the course, students will have engaged with the attributes of the IB learner profile. For example, the requirements of the internal assessment provide opportunities for students to develop every aspect of the profile. For each attribute of the learner profile, a number of references are given below.

Learner profile attribute	
Inquirers	Aims 1, 2 and 8 Practical work and internal assessment
Knowledgeable	Aims 1, 2, 4 and 10 Practical work and internal assessment
Thinkers	Aims 2, 3, 4, 7 and 10 Practical work and internal assessment
Communicators	Aims 2, 4 and 7; external assessment Practical work and internal assessment; group 4 project
Principled	Aims 5, 6 and 9 Practical work and internal assessment: ethical behaviour/practice (*Ethical practice poster, Animal experimentation policy*); academic honesty
Open-minded	Aims 2, 3, 6, 7, 8 and 9 Practical work and internal assessment; group 4 project
Caring	Aims 6, 8 and 9 Practical work and internal assessment; group 4 project; ethical behaviour/practice (*Ethical practice poster, Animal experimentation policy*)
Risk-takers	Aims 1, 3 and 7 Practical work and internal assessment; group 4 project
Balanced	Aims 5, 6, 8, 9 and 10 Practical work and internal assessment
Reflective	Aims 1, 5, 6, 8, 9 and 10 Practical work and internal assessment; group 4 project

Syllabus content

<table>
<tr><th colspan="3" rowspan="2">Syllabus component</th><th colspan="2">Recommended teaching hours</th></tr>
<tr><th>SL</th><th>HL</th></tr>
<tr><td colspan="3">Core</td><td colspan="2">90</td></tr>
<tr><td>1</td><td>Human factors and ergonomics</td><td>• Anthropometrics
• Psychological factors
• Physiological factors</td><td colspan="2">12</td></tr>
<tr><td>2</td><td>Resource management and sustainable production</td><td>• Resources and reserves
• Waste mitigation strategies
• Energy utilization, storage and distribution
• Clean technology
• Green design
• Eco-design</td><td colspan="2">22</td></tr>
<tr><td>3</td><td>Modelling</td><td>• Conceptual modelling
• Graphical modelling
• Physical modelling
• Computer-aided design (CAD)
• Rapid prototyping</td><td colspan="2">12</td></tr>
<tr><td>4</td><td>Final production</td><td>• Properties of materials
• Metals and metallic alloys
• Timber
• Glass
• Plastics
• Textiles
• Composites
• Scales of production
• Manufacturing processes
• Production systems
• Robots in automated production</td><td colspan="2">23</td></tr>
</table>

Syllabus component			Recommended teaching hours SL	Recommended teaching hours HL
5	Innovation and design	• Invention • Innovation • Strategies for innovation • Stakeholders in invention and innovation • Product life cycle • Rogers' characteristics of innovation and consumers • Innovation, design and marketing specifications	13	
6	Classic design	• Characteristics of classic design • Classic design, function and form	8	
Additional higher level (AHL)			**54**	
7	User-centred design	• User-centred design (UCD) • Usability • Strategies for user research • Strategies for UCD • Beyond usability—designing for pleasure and emotion		12
8	Sustainability	• Sustainable development • Sustainable consumption • Sustainable design • Sustainable innovation		14
9	Innovation and markets	• Corporate strategies • Market sectors and segments • Marketing mix • Market research • Branding		13
10	Commercial production	• Just in time (JIT) and just in case (JIC) • Lean production • Computer-integrated manufacturing (CIM) • Quality management • Economic viability		15

Topic 1: Human factors and ergonomics

12 hours

Essential idea: Designers consider three human factors to ensure products meet ergonomic needs.

1.1a Anthropometrics		
Nature of design: Design is human centred and, therefore, designers need to ensure that the products they design are the right size for the user and therefore comfortable to use. Designers have access to data and drawings, which state measurements of human beings of all ages and sizes. Designers need to consider how users will interact with the product or service. Use and misuse is an important consideration. (1.5, 1.18, 1.20)	**Concept and principles:** • Anthropometric data: static and dynamic data, structural and functional data • Primary data versus secondary data • Percentiles and percentile ranges • Range of sizes versus adjustability • Clearance, reach and adjustability **Guidance:** • Collecting anthropometric data considering reliability and limitations • Interpreting percentile tables for user populations • Design contexts where different percentile ranges are used	**International-mindedness:** • A wide selection of anthropometric data is published and regionalized, for example, Asian data versus western European data. The designer must work with data appropriate to the target market. **Theory of knowledge:** • Do the methods of data collection used in design technology have more in common with disciplines in the human sciences or the natural sciences? **Utilization:** • Design technology topic 7 **Aims:** • **Aim 6:** Anthropometric data sets can vary significantly between populations. Particularly in the fashion industry, the variance in these data sets impacts the size range of clothes for particular markets.

1.1b Psychological factors

Nature of design:

Human beings vary psychologically in complex ways. Any attempt by designers to classify people into groups merely results in a statement of broad principles that may or may not be relevant to the individual. Design permeates every aspect of human experience and data pertaining to what cannot be seen such as touch, taste, and smell are often expressions of opinion rather than checkable fact. (1.5, 1.18, 1.20, 2.9)

Concepts and principles:

- Psychological factor data
- Human information processing systems
- Effect of environmental factors
- Alertness
- Perception

Guidance:

- Data in relation to light, smell, sound, taste, temperature and texture as qualitative or quantitative (ordinal/interval)
- Methods of collecting psychological factor data
- Representing the human information processing system using flow diagrams
- Applying the human information processing system to a common task
- Evaluating effects and reasons for a breakdown in the human information processing system
- User responses to environmental factors
- How environmental factors induce different levels of alertness
- The importance of optimizing environmental factors to maximize workplace performance
- Assessing the impact of perception in relation to the accuracy and reliability of psychological factor data

International-mindedness:

- The origin of psychology (as a mainly western academic subject) along with recent neurological insights on a global scale need to be taken into account in applying any psychological factors to global design problems.

Theory of knowledge:

- How might the collection and interpretation of data be affected by the limitations of our sense perception?

Utilization:

- Design technology topic 7
- Biology option A
- Psychology part 1: core

Aims:

- **Aim 3:** The analysis of the human information processing system requires a designer to critically analyse a range of causes and effects to identify where a potential breakdown could occur and the effect it may have.

<table>
<tr><th colspan="3">1.1c Physiological factors</th></tr>
<tr>
<td>Nature of design:

Designers study physical characteristics to optimize the user’s safety, health, comfort and performance. (1.5, 1.18, 1.20, 2.9)</td>
<td>Concepts and principles:
• Physiological factor data
• Comfort and fatigue
• Biomechanics
Guidance:
• Types of physiological factor data available to designers and how they are collected
• How data related to comfort and fatigue informs design decisions
• The importance of biomechanics to the design of different products considering muscle strength, age, user interface and torque</td>
<td>International-mindedness:
• It is important that the physiological factor data are either regional/national data or great care is taken when applying data from one source to a potentially inappropriate target market.
Theory of knowledge:
• This topic is about human factors. How do ethical limitations affect the sort of investigations that can take place where human subjects are involved?
Utilization:
• Design technology topic 7
• Biology topics 6 and 11
• Physics topic 2
• Sports exercise and health topics 1, 2 and 4
Aims:
• Aim 8: Understanding complex biomechanics and designing products to enable full functionality of body parts can return independence and personal and social well-being to an individual.</td>
</tr>
</table>

Topic 2: Resource management and sustainable production — 22 hours

Essential idea: Resource management and sustainable production carefully consider three key issues—consumption of raw materials, consumption of energy, and production of waste—in relation to managing resources and reserves effectively and making production more sustainable.

2.1 Resources and reserves		
Nature of design: As non-renewable resources run out, designers need to develop innovative solutions to meet basic human needs for energy, food and raw materials. The development of renewable and sustainable resources is one of the major challenges of the 21st century for designers. (2.9)	**Concepts and principles:** • Renewable and non-renewable resources • Reserves • Renewability **Guidance:** • The economic and political importance of material and land resources and reserves considering set-up cost, efficiency of conversion, sustainable and constant supply, social impact, environmental impact and decommissioning • Comparison of renewable and non-renewable resources • Positive or negative impact that a development may have on the environment	**International-mindedness:** • The impact of multinational companies when obtaining resources in different countries/regions can be a significant issue for the local population and have major social, ethical and environmental implications. **Theory of knowledge:** • To what extent should potential damage to the environment limit our pursuit of knowledge? **Utilization:** • Design technology topics 4, 8 and 10 • Biology topic 4 • Business management topic 5 • Economics topic 1 • Environmental systems and societies topics 1 and 8 • Physics topic 8

2.1 Resources and reserves		
		Aims: • **Aim 3:** Much of the development of new resources is the product of creating sustainable solutions to existing problems. • **Aim 10:** The legacy of the industrial revolution is now being felt as we face resource depletion. The challenge for designers is to continue to develop products that meet the needs of humans, while conserving the environment for future generations.

Essential idea: Waste mitigation strategies can reduce or eliminate the volume of material disposed to landfill.

2.2 Waste mitigation strategies		
Nature of design: The abundance of resources and raw materials in the industrial age led to the development of a throwaway society, and as resources run out, the many facets of sustainability become a more important focus for designers. The result of the throwaway society is large amounts of materials found in landfill, which can be considered as a new source to mine resources from. (2.7)	**Concepts and principles:** • Re-use • Recycle • Repair • Recondition • Re-engineer • Pollution/waste • Methodologies for waste reduction and designing out waste • Dematerialization • Product recovery strategies at end of life/ disposal • Circular economy—the use of waste as a resource within a closed loop system **Guidance:** • Use and recovery of standard parts at the end of product life • Recovery of raw materials • Reduction of total material and energy throughput of a product or service, and the limitation of its environmental impact through: reduction of raw materials at the production stage; energy and material inputs at the user stage; waste at the disposal stage	**International-mindedness:** • The export of highly toxic waste from one country to another is an issue for all stakeholders. **Theory of knowledge:** • The circular economy can be seen as an example of a paradigm shift in design. Does knowledge develop through paradigm shifts in all areas of knowledge? **Utilization:** • Design technology topics 4, 8 and 10 • Environmental systems and societies topic 8 **Aims:** • **Aim 2:** The exploration of possible solutions to eliminate waste in our society has given rise to ideas developed as part of the circular economy. By redesigning products and processes, the waste from one product can become the raw material of another.

2.2 Waste mitigation strategies		
	• How dematerialization can improve product efficiency by saving, reusing or recycling materials and components • The impacts of dematerialization on each stage of the product life cycle including: material extraction; eco-design; cleaner production; environmentally conscious consumption patterns; recycling of waste • Potential results of successful dematerialization	

Essential idea: There are several factors to be considered with respect to energy and design.

<table>
<tr><th colspan="3">2.3 Energy utilization, storage and distribution</th></tr>
<tr>
<td>Nature of design:
Efficient energy use is an important consideration for designers in today’s society. Energy conservation and efficient energy use are pivotal in our impact on the environment. A designer’s goal is to reduce the amount of energy required to provide products or services using newer technologies or creative implementation of systems to reduce usage. For example, driving less is an example of energy conservation, while driving the same amount but with a higher mileage car is energy efficient. (1.11, 1.16, 2.10)</td>
<td>Concepts and principles:
• Embodied energy
• Distributing energy: national and international grid systems
• Local combined heat and power (CHP)
• Systems for individual energy generation
• Quantification and mitigation of carbon emissions
• Batteries, capacitors and capacities considering relative cost, efficiency, environmental impact and reliability
Guidance:
• Total energy consumed in production (cradle to [factory] gate) and throughout the lifecycle of a product (cradle to grave)
• Batteries are limited to hydrogen fuel cells, lithium, NiCad, lead acid, and LiPo batteries</td>
<td>International-mindedness:
• There are instances of energy sources (for example, oil and electricity) crossing national boundaries through cross-border networks leading to issues of energy security.
Theory of knowledge:
• The Sun is the source of all energy and essential for human existence. Is there some knowledge common to all areas of knowledge and ways of knowing?
Utilization:
• Design technology topics 8 and 10
• Biology topic 4
• Chemistry option C
• Environmental systems and societies topic 2
• Physics topics 5, 8 and 11
Aims:
• Aim 1: As we develop new electronic products, electrical energy power sources remain an ever-important issue. The ability to concentrate electrical energy into ever-decreasing volume and weight is the challenge for designers of electronic products.</td>
</tr>
</table>

Essential idea: Clean technology seeks to reduce waste/pollution from production processes through radical or incremental development of a production system.

2.4 Clean technology		
Nature of design: Clean technology is found in a broad range of industries, including water, energy, manufacturing, advanced materials and transportation. As our Earth's resources are slowly depleted, demand for energy worldwide should be on every designer's mind when generating products, systems and services. The convergence of environmental, technological, economic and social factors will produce more energy-efficient technologies that will be less reliant on obsolete, polluting technologies. (1.11, 1.16, 2.10)	**Concepts and principles:** • Drivers for cleaning up manufacturing: promoting positive impacts; ensuring neutral impact or minimizing negative impacts through conserving natural resources; reducing pollution and use of energy; reducing wastage of energy and resources • International legislation and targets for reducing pollution and waste • End-of-pipe technologies • Incremental and radical solutions • System level solutions **Guidance:** • The role of legislation to provide impetus for manufacturers to clean up manufacturing processes • Advantages and disadvantages of incremental and radical solutions • How manufacturers react to legislation • How legislation can be monitoring and policing	**International-mindedness:** • The development of clean technology strategies for reducing pollution and waste can positively impact local, national and global environments. **Theory of knowledge:** • International targets may be seen to impose the view of a certain culture onto another. Can one group of people know what is best for others? **Utilization:** • Design technology topics 4, 8 and 10 • Chemistry option C • Environmental systems and societies topics 1 and 4 **Aims:** • **Aim 5:** The legislation for reducing pollution often focuses on the output and, therefore, end-of-pipe technologies. By implementing ideas from the circular economy, pollution is negated and waste eliminated.

Essential idea: Green design integrates environmental considerations into the design of a product without compromising its integrity.

<table>
<tr><th colspan="3">2.5 Green design</th></tr>
<tr>
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Nature of design:

The starting point for many green products is to improve an existing product by redesigning aspects of it to address environmental objectives. The iterative development of these products can be incremental or radical depending on how effectively new technologies can address the environmental objectives. When newer technologies are developed, the product can re-enter the development phase for further improvement. (1.4)

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Concepts and principles:

- Strategies for green design (incremental and radical)
- Green legislation
- Timescale to implement green design
- Drivers for green design (consumer pressure and legislation)
- Design objectives for green products
- Strategies for designing green products
- The prevention principle
- The precautionary principle

Guidance:

- How strategies for green design often involve a focus on one or two environmental objectives when designing or re-designing products
- How green legislation encourages incremental rather than radical changes
- How environmental legislation has encouraged the design of products that tackle specific environmental issues
- How design objectives for green products address three broad environmental categories—materials, energy and pollution/waste
- Evaluating products in terms of: consumption of raw materials; packaging; incorporation of toxic chemicals; energy in production and use; end-of-life disposal; production methods; and atmospheric pollutants

</td>
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International-mindedness:

- The ability and will of different countries to enact environmental legislation varies greatly.

Theory of knowledge:

- Green issues are an area where experts sometimes disagree. On what basis might we decide between the judgments of experts if they disagree?

Utilization:

- Design technology topics 4, 5 and 8
- Environmental systems and societies topic 1
- Visual arts

Aims:

- **Aim 9:** The purpose of green design is to ensure a sustainable future for all.

</td>
</tr>
</table>

Essential idea: Eco-design considers the design of a product throughout its life cycle (from cradle to grave) using lifecycle analysis.

2.6 Eco-design		
Nature of design: Consideration of the environmental impact of any product, service or system during its life cycle should be instigated at the earliest stage of design and continue through to disposal. Designers should have a firm understanding of their responsibility to reduce the ecological impact on the planet. Eco-design concepts currently have a great influence on many aspects of design. (1.16)	**Concepts and principles:** • Timescale for implementing eco-design • The "cradle to grave" and "cradle to cradle" philosophy • Life cycle analysis (LCA) • LCA stages: pre-production; production; distribution including packaging; utilization and disposal • Environmental considerations • Environmental impact assessment matrix • Product life cycle stages: the role of the designer, manufacturer and user • The major considerations of the United Nations Environmental Programme Manual on Eco-design • "Design for the environment" software • Converging technologies **Guidance:** • How designers use LCA to assess and balance environmental impact over a product's life cycle • Benefits of organizing the life cycle stages and the environmental considerations into an environmental impact assessment matrix in which elements differ in importance according to the particular design context	**International-mindedness:** • The differing stages of economic development of different countries/regions and their past and future contributions to global emissions is an issue. **Theory of knowledge:** • There is no waste in nature. Should areas of knowledge look at natural processes beyond human endeavour? **Utilization:** • Design technology topics 4, 5 and 8 • Environmental systems and societies topic 1 • Visual arts **Aims:** • **Aim 3:** The smart phone is an innovative example of converging technologies that combines multiple technologies into one space-saving device. The resultant reduction of materials, and energy used in production and distribution has environmental benefits.

2.6 Eco-design		
	• How LCA enables data to be compared and acts as a useful tool for communicating with clients/ outside agencies • How LCA can be used to identify potential conflicts between clients/outside agencies, which need to be resolved through prioritization • Consider complexity, time and expense of LCA • The use of checklists to guide the design team during a product's design development stages • How "design for the environment" software is used to assist designers in the assessment of environmental implications and particular facets of a design • Advantages and disadvantages of converging technology	

Topic 3: Modelling

12 hours

Essential idea: A conceptual model originates in the mind and its primary purpose is to outline the principles, processes and basic functions of a design or system.

3.1 Conceptual modelling		
Nature of design: Designers use conceptual modelling to assist their understanding by simulating the subject matter they represent. Designers should consider systems, services and products in relation to what they should do, how they should behave, what they look like and whether they will be understood by the users in the manner intended. (1.2, 1.3, 1.8)	**Concepts and principles:** • The role of conceptual modelling in design • Conceptual modelling tools and skills **Guidance:** • How conceptual models are used to communicate with oneself and others • How conceptual models vary in relation to the context • How the designer visualizes concepts, design thinking and learning • Advantages and disadvantages of using conceptual modelling	**Theory of knowledge:** • In the construction of a model, how can we know which aspects of the world to include and which to ignore? **Utilization:** • Design technology internal assessment • Chemistry topic 6 • Environmental systems and societies topic 1 • Visual arts **Aims:** • **Aim 7:** The starting point for solving a problem springs from an idea developed in the mind. A detailed exploration of the idea is vital to take it from the intangible to the tangible, along with the ability to articulate the idea to others.

Essential idea: Graphical models are used to communicate design ideas.

3.2 Graphical modelling		
Nature of design: Graphical models can take many forms, but their prime function is always the same—to simplify the data and present it in such a way that understanding of what is being presented aids further development or discussion. Designers utilize graphical modelling as a tool to explore creative solutions and refine ideas from the technically impossible to the technically possible, widening the constraints of what is feasible. (1.13, 3.7)	**Concepts and principles:** • 2D and 3D graphical models • Perspective, projection and scale drawings • Sketching versus formal drawing techniques • Part and assembly drawings **Guidance:** • How graphical models are used to communicate with oneself and others • How the choice of graphical models varies in relation to the context • Advantages and disadvantages of using different graphical models	**Theory of knowledge:** • Are there aspects of the world that are not amenable to modelling? • To what extent does graphical communication shape and limit our knowledge? **Utilization:** • Design technology internal assessment • Visual arts **Aims:** • **Aim 2:** The development of ideas through graphical models allows designers to explore and deepen their understanding of a problem and context of use.

Essential idea: A physical model is a three-dimensional, tangible representation of a design or system.

3.3 Physical modelling		
Nature of design: Designers use physical models to visualize information about the context that the model represents. It is very common for physical models of large objects to be scaled down and smaller objects scaled up for ease of visualization. The primary goal of physical modelling is to test aspects of a product against user requirements. Thorough testing at the design development stage ensures that an appropriate product is developed. (1.2, 1.13, 3.2)	**Concepts and principles:** • Scale models • Aesthetic models • Mock-ups • Prototypes • Instrumented models **Guidance:** • Applications of physical models • Use of instrumented models to measure the level of a product's performance and facilitate ongoing formative evaluation and testing • Advantages and disadvantages of using physical models	**Theory of knowledge:** • Models that only show aspects of reality are widely used in design. How can they lead to new knowledge? **Utilization:** • Design technology topics 1, 5 and 7 • Design technology internal assessment • Visual arts **Aims:** • **Aim 4:** Physical modelling not only allows designers to explore and test their ideas, but to also present them to others. Engaging clients, focus groups and experts to interact with physical models of products allows designers to gain valuable feedback that enable them to improve the design and product-user interface.

Essential idea: A computer-aided design is the generation, creation, development and analysis of a design or system using computer software.

3.4 Computer-aided design (CAD)		
Nature of design: As technologies improve and the software becomes more powerful, so do the opportunities for designers to create new and exciting products, services and systems. Greater freedom in customization and personalization of products has a significant impact on the end user. The ability to virtually prototype, visualize and share designs enhances the whole design cycle from data analysis through to final designs. (1.14)	**Concepts and principles:** • Types of CAD software • Surface and solid models • Data modelling including statistical modelling • Virtual prototyping • Bottom-up and top-down modelling • Digital humans: motion capture, haptic technology, virtual reality (VR), and animation • Finite element analysis (FEA) **Guidance:** • Advantages and disadvantages of using computer-aided modelling • How data models structure data through database models • Design of information systems to enable the exchange data • How haptic technology, motion capture, VR and animation can be used to simulate design scenarios and contexts • Comparison of FEA with testing physical models • Use of FEA systems when designing and developing products	**International-mindedness:** • Improved communication technologies allow designs to be developed collaboratively by different global teams on a 24/7 basis. **Theory of knowledge:** • How is new knowledge acquired through the use of digital models? • Does technology allow us to gain knowledge that our human senses are unable to gain? **Utilization:** • Design technology topics 4, 7 and 10 • Design technology internal assessment • Visual arts **Aims:** • **Aim 10:** The use of CAD to simulate the conditions in which a product will be used allows the designer to gain valuable data at low cost. For example, simulating the flow of air across a car exterior negates the need for a car and wind tunnel.

Essential idea: Rapid prototyping is the production of a physical model of a design using three-dimensional CAD data.

3.5 Rapid prototyping		
Nature of design: The growth in computing power has had a major impact on modelling with computer-aided manufacture. Rapid software and hardware developments allow new opportunities and exciting new technologies to create dynamic modelling of ever-greater complexity. Models can be simulated by designers using software, tested and trialled virtually before sending to a variety of peripheral machines for prototype manufacture in an ever-increasing range of materials. The ease of sending this digital data across continents for manufacture of prototypes has major implications for data and design protection. (1.19)	**Concepts and principles:** • Stereolithography • Laminated object manufacturing (LOM) • Fused deposition modelling (FDM) • Selective laser sintering (SLS) **Guidance:** • Different types of 3D printing techniques • Advantages and disadvantages of rapid prototyping techniques	**International-mindedness:** • The high cost of some new processes does not allow for their rapid dissemination globally. **Theory of knowledge:** • Which ways of knowing do we use to interpret indirect evidence gathered through the use of technology? **Utilization:** • Design technology topics 4, 7 and 10 • Design technology internal assessment **Aims:** • **Aim 10:** The increasing effectiveness of rapid prototyping techniques in terms of both cost and speed enables designers to create complex physical models for testing.

Topic 4: Final production — 23 hours

Essential idea: Materials are selected for manufacturing products based primarily on their properties.

4.1 Properties of materials		
Nature of design: The rapid pace of scientific discovery and new technologies has had a major impact on material science, giving designers many more materials from which to choose for their products. These new materials have given scope for "smart" new products or enhanced classic designs. Choosing the right material is a complex and difficult task with physical, aesthetic, mechanical and appropriate properties to consider. Environmental, moral and ethical issues surrounding choice of materials for use in any product, service or system also need to be considered. (2.1)	**Concepts and principles:** • Physical properties: mass, weight, volume, density, electrical resistivity, thermal conductivity, thermal expansion and hardness • Mechanical properties: tensile and compressive strength, stiffness, toughness, ductility, elasticity, plasticity, Young's modulus, stress and strain • Aesthetic characteristics: taste, smell, appearance and texture • Properties of smart materials: piezoelectricity, shape memory, photochromicity, magneto-rheostatic, electro-rheostatic and thermoelectricity **Guidance:** • Design contexts where physical properties, mechanical properties and/or aesthetic characteristics are important • Design contexts where properties of smart materials are exploited • Using stress/strain graphs and material selection charts to identify appropriate materials	**International-mindedness:** • Smart materials are likely to be developed in specific regions/countries and their benefits can be limited globally in the short term. **Theory of knowledge:** • Through specialized vocabularies, is it the case that shaping of knowledge is more dramatic in some areas of knowledge than others? **Utilization:** • Design technology topics 2, 3, 8 and 10 • Design technology internal assessment • Biology topic 2 • Chemistry option A • Physics topic 7 • Visual arts

4.1 Properties of materials		
		Aims: • **Aim 2:** Materials are often developed by materials engineers to have specific properties. The development of new materials allows designers to create new products, which solve old problems in new ways. For example, the explosion of plastic materials following the second world war enabled products to be made without using valuable metals.

Essential idea: Materials are classified into six basic groups based on their different properties.

4.2a Metals and metallic alloys		
Nature of design: Typically hard and shiny with good electrical and thermal conductivity, metals are a very useful resource for the manufacturing industry. Most pure metals are either too soft, brittle or chemically reactive for practical use and so understanding how to manipulate these materials is vital to the success of any application. (2.2)	**Concepts and principles:** • Extracting metal from ore • Grain size • Modifying physical properties by alloying, work hardening and tempering • Design criteria for super alloys • Recovery and disposal of metals and metallic alloys **Guidance:** • An overview of the metal extraction process is sufficient • Super alloy design criteria include creep and oxidation resistance • Contexts where different metals and metallic alloys are used	**International-mindedness:** • Extraction takes place locally with added value often occurring in another country. **Theory of knowledge:** • How does classification and categorization help and hinder the pursuit of knowledge? **Utilization:** • Design technology topics 2 and 10 • Chemistry topic 4 and option A **Aims:** • **Aim 5:** Design for disassembly is an important aspect of sustainable design. Valuable metals, such as gold and copper, are being recovered from millions of mobile phones that have gone out of use following the end of product life. Some laptops and mobile phones can be disassembled very quickly without tools to allow materials to be recovered easily.

4.2b Timber		
Nature of design: Timber is a major building material that is renewable and uses the Sun's energy to renew itself in a continuous cycle. While timber manufacture uses less energy and results in less air and water pollution than steel or concrete, consideration needs to be given to deforestation and the potential negative environmental impact the use of timber can have on communities and wildlife. (3.6)	**Concepts and principles:** • Characteristics of natural timber: hardwood and softwood • Characteristics of man-made timbers • Treating and finishing timbers • Recovery and disposal of timbers **Guidance:** • Characteristics include tensile strength, resistance to damp environments, longevity, aesthetic properties • Design contexts in which different timbers would be used	**International-mindedness:** • The demand for high-quality hardwoods results in the depletion of ancient forests in some regions/countries impacting on the environment in multiple ways. **Theory of knowledge:** • Designers are moving from exploitation of resources towards conservation and sustainability. Is the environment at the service of man? **Utilization:** • Design technology topics 2 and 10 **Aims:** • **Aim 9:** Designers have great influence over the materials that they specify for products. The move towards using timber from sustainably managed forestry gives consumers confidence that rare species found in rainforests have an opportunity to recover.

4.2c Glass		
Nature of design: The rapid pace of technological discoveries is very evident in the manufacture and use of glass in electronic devices. Different properties have been presented in glass for aesthetic or safety considerations for many years but the future of glass seems to be interactivity alongside electronic systems. The structure of glass is not well understood, but as more is learned, its use is becoming increasingly prominent in building materials and structural applications. (2.2)	**Concepts and principles:** • Characteristics of glass • Applications of glass • Recovery and disposal of glass **Guidance:** • Characteristics include transparency, colour and strength • Design contexts in which different types of glass are used	**Utilization:** • Design technology topics 2 and 10 • Chemistry option A **Aims:** • **Aim 6:** The earliest found examples of glass objects come from the third millennium BCE, and up until the 1850s glass was considered a luxury item. Since then, glass has permeated and revolutionized many aspects of human life and culture in diverse fields such as the arts, architecture, electronics and communication technologies.

4.2d Plastics		
Nature of design: Most plastics are produced from petrochemicals. Motivated by the finiteness of oil reserves and threat of global warming, bio-plastics are being developed. These plastics degrade upon exposure to sunlight, water or dampness, bacteria, enzymes, wind erosion and in some cases pest or insect attack, but in most cases this does not lead to full breakdown of the plastic. When selecting materials, designers must consider the moral, ethical and environmental implications of their decisions. (3.6)	**Concepts and principles:** • Raw materials for plastics • Structure of thermoplastics • Structure of thermosetting plastics • Temperature and recycling thermoplastics • Recovery and disposal of plastics **Guidance:** • Properties of PP, PE, HIPS, ABS, PET and PVC • Properties of polyurethane, urea-formaldehyde, melamine resin and epoxy resin • Design contexts in which different types of plastics are used	**International-mindedness:** • The raw material for plastics (mainly oil) is extracted in a country, exported to other countries where conversion to plastics takes place and these are re-exported at considerable added value. **Utilization:** • Design technology topics 2 and 10 • Chemistry option A **Aims:** • **Aim 3:** Early plastics used from 1600 BCE through to 1900 CE were rubber based. Prompted by the need for new materials following the first world war, the invention of Bakelite and polyethylene in the first half of the 20th century sparked a massive growth of plastic materials and as we identify the need for new materials with particular properties, the development of new plastics continues.

4.2e Textiles		
Nature of design: The continuing evolution of the textiles industry provides a wide spread of applications from high-performance technical textiles to the more traditional clothing market. More recent developments in this industry require designers to combine traditional textile science and new technologies leading to exciting applications in smart textiles, sportswear, aerospace and other potential areas. (2.2)	**Concepts and principles:** • Raw materials for textiles • Properties of natural fibres • Properties of synthetic fibres • Conversion of fibres to yarns • Conversion of yarns into fabrics: weaving, knitting, lacemaking, and felting • Recovery and disposal of textiles **Guidance:** • Properties of wool, cotton and silk • Properties of nylon, polyester and Lycra® • Consider absorbency, strength, elasticity and the effect of temperature • Design contexts in which different types of textiles are used	**International-mindedness:** • The economics and politics of the production and sale of clothing by multinationals can be a major ethical issue for consumers and the workforce. **Theory of knowledge:** • Designers use natural and man-made products. Do some areas of knowledge see an intrinsic difference between these? **Utilization:** • Design technology topics 2 and 10 **Aims:** • **Aim 5:** There are many ethical considerations attached to the production of natural fibres. The strongest natural silk known to man is harvested from silk spiders and notoriously difficult to obtain, and labour intensive. In an effort to produce higher yields, scientists have altered the genome of goats so that they produce the same silk proteins in their milk.

4.2f Composites		
Nature of design: Composites are an important material in an intensely competitive global market. New materials and technologies are being produced frequently for the design and rapid manufacture of high-quality composite products. Composites are replacing more traditional materials as they can be created with properties specifically designed for the intended application. Carbon fibre has played an important part in weight reduction for vehicles and aircraft. (2.2)	**Concepts and principles:** • Form: fibres/sheet/particles and matrix • Process: weaving, moulding, pultrusion and lamination • Composition and structure of composites: concrete, engineered wood, plywood, particleboard, fibreglass, Kevlar®, carbon-reinforced plastic, laminated veneer lumber (LVL) **Guidance:** • Fibres/sheets/particles: textiles, glass, plastics and carbon • Matrix: thermoplastics, thermosetting plastics, ceramics, metals • Advantages and disadvantages of composite materials • Design contexts in which different types of composite materials are used	**International-mindedness:** • Many composite materials are expensive to produce and their dissemination globally is limited. **Utilization:** • Design technology topics 2, 5 and 10 • Chemistry option A **Aims:** • **Aim 1:** As designers develop new products, they should always be aware of the materials available. In an effort to increase productivity and lose weight, carbon fibre parts are often glued together. The use of an epoxy adhesive rather than traditional fastening methods allows manufacturers to create complex shapes quickly and easily. These materials and methods are being transferred to consumer products.

Essential idea: The scale of production depends on the number of products required.

4.3 Scales of production		
Nature of design: Decisions on scale of production are influenced by the volume or quantities required, types of materials used to make the products and the type of product being manufactured. There are also considerations of staffing, resources and finance. (1.15)	**Concepts and principles:** • One-off, batch production and continuous flow • Mass customization **Guidance:** • Selecting an appropriate scale of production • Advantages and disadvantages of different scales of production	**International-mindedness:** • Mass customization enables global products to become individual items. **Utilization:** • Design technology topics 3 and 10 • Design technology internal assessment • Business management topic 5 **Aims:** • **Aim 9:** The growing phenomenon of mass customization brings consumers into the design process, allowing them to make choices that make a product unique, to make it their own. Companies have developed "design stations" in their retail stores where consumers can create virtual 3D models, "try them out" using digital technology and place their order.

Essential idea: Different manufacturing processes have been developed to innovate existing products and create new products.

4.4 Manufacturing processes		
Nature of design: Designers sometimes engineer products in such a way that they are easy to manufacture. Design for manufacture (DfM) exists in almost all engineering disciplines, but differs greatly depending on the manufacturing technologies used. This practice not only focuses on the design of a product's components, but also on quality control and assurance. (1.11)	**Concepts and principles:** • Additive techniques: paper-based rapid prototyping, laminated object manufacture (LOM), stereolithography • Wasting/subtractive techniques: cutting, machining, turning and abrading • Shaping techniques: moulding, thermoforming, laminating, casting, knitting, weaving • Joining techniques: permanent and temporary, fastening, adhering, fusing **Guidance:** • Selecting appropriate manufacturing techniques based on material characteristics (form, melting/softening point), cost, capability, scale of production, desired properties • Advantages and disadvantages of different techniques • Design contexts where different manufacturing processes are used	**International-mindedness:** • More expensive modern processes tend to take place in technologically advanced regions/countries. **Utilization:** • Design technology topics 2, 3 and 10 • Design technology internal assessment **Aims:** • **Aim 8:** Advancements in 3D printing have resulted in the ability to have a 3D printer at home. Consumers can download plans for products from the internet and print these products themselves.

Essential idea: The development of increasingly sophisticated production systems is transforming the way products are made.

4.5 Production systems		
Nature of design: As a business grows in size and produces more units of output, then it will aim to experience falling average costs of production—economies of scale. The business is becoming more efficient in its use of inputs to produce a given level of output. Designers should incorporate internal and external economies of scale when considering different production methods and systems for manufacture. (1.11)	**Concepts and principles:** • Craft production • Mechanized production • Automated production • Assembly line production • Mass production • Mass customization • Computer numerical control (CNC) • Production system selection criteria • Design for manufacture (DfM): design for materials, design for process, design for assembly, design for disassembly • Adapting designs for DfM **Guidance:** • Advantages and disadvantages of different production systems • Impact of different production systems on the workforce and environment • Production system selection criteria include time, labour, skills and training, health and safety, cost, type of product, maintenance, impact on the environment and quality management • Design contexts where different production systems are used	**International-mindedness:** • The geographical distribution of different modes of production is an economic and political issue. **Theory of knowledge:** • The increased dependency on automation and robots has affected craftsmanship. How has technology affected traditional ways of knowing? **Utilization:** • Design technology topics 2, 3, 6 and 10 • Design technology internal assessment • Economics **Aims:** • **Aim 7:** The design of a production system requires a complete understanding of a product, its function and the quality of finish. Each system can be unique and specific to the product it is creating, often requiring the designers to adapt their design to be manufactured using certain methods.

Essential idea: The development of increasingly sophisticated robotic manufacturing systems is transforming the way products are made.

4.6 Robots in automated production		
Nature of design: Designers should consider the benefits of increased efficiency and consistency when using robots in production and be able to explore the latest advances in technology to ensure the optimum manufacturing process is used. However, a good designer will also understand their responsibility to consider the moral and ethical issues surrounding increased use of automation, and the historical impact of lost jobs. (2.5)	**Concepts and principles:** • Primary characteristics of robots: work envelope and load capacity • Single-task robots • Multi-task robots • Teams of robots • Machine to machine (M2M) **Guidance:** • Advantages and disadvantages of using robotic systems in production • Consider first, second, and third generation robots	**International-mindedness:** • The use of robots in automated production can depend on the local cost of manual labour. **Theory of knowledge:** • Technology in the form of robots currently serves man. Is man's place secure? Will the nature of man change due to technological enhancement? Will he be superseded altogether by technological developments? **Utilization:** • Design technology topics 1, 8 and 10 **Aims:** • **Aim 8:** The introduction of robots to an assembly line has had a major impact on the labour force, often making skilled workers redundant in favour of a technician who can maintain and equip a large number of robots.

Topic 5: Innovation and design

13 hours

Essential idea: The protection of a novel idea of how to solve a problem is a major factor in commercial design.

5.1 Invention		
Nature of design: Invention by lone inventors or in collaborative, creative teams is at the forefront of design. Designers must not only be creative and innovative, but also understand the concepts that will make a new product viable. A designer must use imagination and be firmly grounded in factual and procedural knowledge while remembering the needs and limitations of the end user. (2.3, 2.4)	**Concepts and principles:** • Drivers for invention • The lone inventor • Intellectual property (IP) • Strategies for protecting IP: patents, trademarks, design protection, copyright. • First to market • Shelved technologies **Guidance:** • Drivers for invention include personal motivation to express creativity/for personal interest, scientific or technical curiosity, constructive discontent, desire to make money, desire to help others • The advantages and disadvantages of being a lone inventor	**International-mindedness:** • The role of intellectual property and patents in stifling or promoting inventions globally needs to be considered, especially with regard to the inequalities between countries. **Theory of knowledge:** • What is the role of imagination in invention? Are there limits to what can be imagined? • Sometimes there are unforeseen consequences of inventions. To what extent might lack of knowledge be an excuse for unethical conduct? **Utilization:** • Design technology topics 2, 3, 4, 6, 7, 9 • Design technology internal assessment

5.1 Invention		
	• Benefits of IP include differentiating a business from competitors, selling or licensing to provide revenue streams, offering customers something new and different, marketing/branding, its value as an asset • IP symbols and their application to products and services: patent pending, ™, ®, ©, ℠ • The effectiveness of strategies for protecting IP • Reasons why some innovators decide not to protect their IP and alternative strategies to ensure success • Reasons why some patented inventions are shelved	**Aims:** • **Aim 1:** Inventions are often the result of an individual or group's curiosity about whether something can be done or a problem can be solved. On occasion, inventions are the result of an individual's curiosity about something other than the product that they finally develop. These inventions include microwave ovens, ink-jet printers and Post-it® notes.

Essential idea: There are many different types of innovation.

5.2 Innovation		
Nature of design: Designers will be successful in the marketplace when they solve long-standing problems, improve on existing solutions or find a “product gap”. The constant evaluation and redevelopment of products is key, with unbiased analysis of consumers and commercial opportunities. (1.1)	**Concepts and principles:** • Invention and innovation • Categories of innovation: sustaining innovation, disruptive innovation, process innovation • Innovation strategies for design: architectural innovation, modular innovation, configurational innovation • Innovation strategies for markets: diffusion and suppression **Guidance:** • Reasons why few inventions become innovations • Examples of products within the categories of innovation • Examples where innovation strategies have been used for products	**International-mindedness:** • Innovations may have positive consequences in some countries/regions and negative ones in others. **Theory of knowledge:** • Design is always looking to the future and new development. Do other areas of knowledge have universal, timeless truths or are they continually in flux? **Utilization:** • Design technology topics 3, 8, 9, 10 • Design technology internal assessment • Business management topic 5 **Aims:** • **Aim 4:** In order for an invention to become an innovation, the idea of the product needs to be effectively communicated. The communication can take many forms and be between many stakeholders.

Essential idea: Designers have a range of strategies for innovation.

5.3 Strategies for innovation		
Nature of design: Companies encourage advancements in technology and services, usually by investing in research and development (R&D) activities. Even though the R&D may be carried out by a range of different experts from varied fields of research, the development process is often based on common principles and strategies to identify the direction of development. This methodology structures the R&D of new technologies and services. (1.7)	**Concepts and principles:** • Act of insight • Adaptation • Technology transfer • Analogy • Chance • Technology push • Market pull **Guidance:** • Design contexts where each strategy has been applied	**Theory of knowledge:** • Design is continually changing due to its openness to new ideas. Do other areas of knowledge recognize new influences to the same extent? **Utilization:** • Design technology topics 3, 7, 8 and 9 • Design technology internal assessment **Aims:** • **Aim 6:** Innovation should always occur in context and a deep understanding of the culture as well as the behaviours, needs and wants of the consumer is required.

Essential idea: There are three key roles in invention and innovation, which can be shared by one or more people.

<table>
<tr><th colspan="3">5.4 Stakeholders in invention and innovation</th></tr>
<tr>
<td>Nature of design:

Collaborative generation of knowledge and high efficiency information flow allow for diversity, increased resilience, reliability and stability within an organization. Through participatory research, stakeholders can make full use of the resulting innovation and invention, by transferring findings relevant to the sector in which they are positioned. A designer’s increased awareness through shared industry knowledge enhances profitability and policy. (1.17)</td>
<td>Concepts and principles:

• The inventor, the product champion, the entrepreneur
• The inventor as a product champion and/or entrepreneur
• A multidisciplinary approach to innovation

Guidance:

• Roles of the product champion and entrepreneur in the innovation of products and systems
• Reasons why inventors often take the role of product champion and/or entrepreneur
• The advantages and disadvantages of multidisciplinary teams</td>
<td>Theory of knowledge:

• Design favours collective wisdom. Do other areas of knowledge value collaborative thinking?

Utilization:

• Design technology topics 6, 7 and 9

Aims:

• Aim 7: On occasion, the inventor needs to act as both entrepreneur and product champion. The adoption of these additional roles requires a significant amount of learning to take an idea from the mind, realize it and then diffuse it successfully into the marketplace.</td>
</tr>
</table>

Essential idea: There are several key stages in the product life cycle.

5.5 Product life cycle		
Nature of design: Designers need to consider the whole product cycle of potential products, services and systems throughout the design cycle and beyond. Products may have an impact not only on the direct consumer but also on society at large and the environment. (1.16)	**Concepts and principles:** • Key stages of the product life cycle: launch, growth, maturity, decline • Obsolescence: planned, style (fashion), functional, technological • Predictability of the product life cycle • Product versioning/generations **Guidance:** • Examples of products at different stages of the product life cycle including those new to the market and classic designs • Length of the product life cycle considering the effect of technical development and consumer trends • Advantages and disadvantages for a company of introducing new versions and generations of a product	**International-mindedness:** • The transition from a linear to a circular economy in the move towards sustainable societies has major implications for the ideas associated with product life cycle. **Theory of knowledge:** • Design considers areas other than man in its thinking. Are other areas of knowledge confined to human influence and values? **Utilization:** • Design technology topics 1, 3, 6, 8 and 9 • Design technology internal assessment • Environmental systems and societies topic 8 • Business management topic 4 **Aims:** • **Aim 2:** An understanding of the product life cycle allows the designer to design a product with obsolescence in mind. Doing this at the design stage can potentially eliminate the effect of a product on the environment when it is no longer in use.

Essential idea: Innovations take time to diffuse into a target audience.

5.6 Rogers' characteristics of innovation and consumers		
Nature of design: Rogers' four main elements that influence the spread of new ideas (innovation, communication channels, time and a social system) rely heavily on human capital. The ideas must be widely accepted in order to be self-sustainable. Designers must consider various cultures and communities to predict how, why and at what rate new ideas and technology will be adopted. (1.7)	**Concepts and principles:** • Diffusion and innovation • The impact of Rogers' characteristics on consumer adoption of an innovation • Social roots of consumerism • The influence of social media on the diffusion of innovation • The influence of trends and the media on consumer choice • Categories of consumers in relation to technology adoption **Guidance:** • Examples of product innovations for each of Rogers' characteristics • The impact of Rogers' characteristics on consumer adoption of an innovation can be considered in terms of relative advantage, compatibility, complexity, observability, trialability • The social roots of consumerism include lifestyle, values and identity • Issues for companies in the global marketplace when attempting to satisfy consumer needs in relation to lifestyle, values and identity • Categories of consumers include innovators, early adopters, early majority, late majority, laggards	**International-mindedness:** • The origin of Rogers' theory in one or two areas may lead to inappropriate application on a global basis. Positive and negative aspects may be opposite in different regions/countries. **Theory of knowledge:** • Design takes into account cultural differences. Are other areas of knowledge universal or culture specific? **Utilization:** • Design technology topics 6, 8 and 9 • Business management topic 4 **Aims:** • **Aim 10:** By categorizing consumers, the designer can identify particular segments with a market sector to gain feedback. By engaging with these stereotypes, the designer can utilize their experiences with a prototype in order to guide further development.

Essential idea: Successful innovations typically start with detailed design and marketing specifications.

5.7 Innovation, design and marketing specifications		
Nature of design: Designers must establish clear parameters for a marketing specification in order to create unique and creative solutions to a problem. Designers need to collect valid and useful data from the target market and audience throughout the design cycle to ensure the specification includes certain essential components. (1.9, 1.10)	**Concepts and principles:** • Target markets • Target audiences • Market analysis • User need • Competition • Research methods • Design specifications **Guidance:** • How market sectors and segments can be used to establish target markets • How a target audience is used to establish the characteristics of users • Design contexts for different target markets and audiences	**International-mindedness:** • The characteristics of users in different countries/regions need to be taken into account. Cultural differences may play a major role. **Theory of knowledge:** • Design is evidence-based. How do other areas of knowledge value the importance of evidence? **Utilization:** • Design technology topics 1, 2, 3, 4, 7 and 9 • Design technology internal assessment • Business management topic 4 **Aims:** • **Aim 4:** The ability to transform their research findings into a series of specifications is a skill that designers must develop to become successful. Being able to express parameters and requirements succinctly allows the designer to develop focused solutions to the design problem and meet a client or the target market's wants and needs.

Topic 6: Classic design

8 hours

Essential idea: A classic design has a timeless quality, which is recognized and remains fashionable.

6.1 Characteristics of classic design		
Nature of design: A classic design is not simply defined by how well it functions or its impact. Classic designs can be recognized as from their design movement/era. Yet, originality—whether it is evolutionary or revolutionary—seems to be the trait that makes a product "timeless". (3.10)	**Concepts and principles:** • Image • Status and culture • Obsolescence • Mass production • Ubiquitous/omnipresence • Dominant design **Guidance:** • How image makes a classic design instantly recognizable and provokes emotional reactions • How a classic design defies obsolescence and transcends its original function • How the role of mass production contributes to a product reaching classic design status • How the constant presence of a product in a changing context leads to classic design status • How classic designs are dominant in the marketplace and difficult to change	**International-mindedness:** • Classic designs are often recognized across culture and hold iconic status. **Theory of knowledge:** • Classic design often appeals to our emotions. Are emotions universal? **Utilization:** • Design technology topics 1, 4, 5, 9 and 10 • Visual arts **Aims:** • **Aim 8:** The iconic status of classic designs is often attributed to them being "breakthrough products".

Essential idea: For a design to become a classic design, the form can transcend the function.

<table>
<tr><th colspan="3">6.2 Classic design, function and form</th></tr>
<tr>
<td>Nature of design:

Classic design holds “form follows function” as a fundamental principle, but this is not always evident in practice. Some products are so well designed with function as their primary goal, that their use is intuitive. As designers develop new technologies, the lines between the form and function of a product continue to blur. (3.3)</td>
<td>Concepts and principles:
• Form versus function
• Retro-styling
• Conflict and compromise
• Practical function versus psychological function
Guidance:
• How retro-styling a new product needs to respect and understand the original form and underlying structure before making changes
• The tension between form and function when developing new products based on a classic design
• Comparison of retro-styled products with the original production models in relation to form and function
• Identify products where either practical function or psychological function has been the determining factor in the design</td>
<td>International-mindedness:
• The emergence of retro-styling products as new technologies are developed relate to the emotional response that comes with nostalgia. This is often not only different between countries and between generations, but at the same time can transcend both.
Theory of knowledge:
• Is aesthetic value purely a subjective matter?
Utilization:
• Design technology topics 1, 3, 5, 7 and 9
• Visual arts
Aims:
• Aim 6: The balance between function and form is often an area of difficulty for the designer. If a product is purely functional, it may be lacking in appeal to consumers, no matter how good it may be at completing its job. Often we are drawn to products that have been developed with form as a primary consideration. The human psyche appreciates beauty.</td>
</tr>
</table>

Topic 7: User-centred design (UCD)

12 hours

Essential idea: The fundamental principle of UCD is that understanding the needs of the users is the key to designing the best products and services.

7.1 User-centred design (UCD)		
Nature of design: A designer must consider the needs, wants and limitations of the end user within every element of the design cycle. The ability to identify how users will interact with a product, service or system is vital for its success. To achieve this, designers must be able to acquire and analyse valid data without making assumptions about how the product may be used. (3.1)	**Concepts and principles:** • The designer needs to have a deep understanding of the user, task and the environment. • The process is iterative, led by the user and developed through user-centred evaluation. • The product must address the whole user experience. • UCD design teams are multidisciplinary. • The five stages of UCD: research, concept, design, implementation, launch • Inclusive design **Guidance:** • UCD design teams may include anthropologists, ethnographers and psychologists. • Inclusive design requires designing universally accessible products for all users including those with physical, sensory, perceptual and other challenges and impairments.	**International-mindedness:** • Even though the task addressed through UCD may not change from region to region, there can be an impact on the success of a global product due to variations in users and environments. **Utilization:** • Design technology topics 1, 5, and 9 • Design technology internal assessment • Business management units 4 and 5 **Aims:** • **Aim 5:** The ability to put aside one's own ideas and bias is essential for UCD. Designers must act with integrity and not project their own ideas of what the user requirements are when trying to create technological solutions to their problems.

Essential idea: Usability is about how easy it is to use a product or system.

7.2 Usability		
Nature of design: A design team should be "user" driven and frequent contact with potential users is essential. To understand how a product, service or system may be used, the designer must consider the prior knowledge and experience of the users, as well as their typical psychological responses. Evaluation methods that utilize appropriate testing and trialling strategies must be used to determine these aspects. (1.5, 1.16, 1.18)	**Concepts and principles:** • Usability objectives • Enhanced usability • Characteristics of good user-product interfaces • Population stereotypes **Guidance:** • Usability objectives include usefulness, effectiveness, learnability, attitude (likeability) • Benefits of enhanced usability include product acceptance, user experience, productivity, user error, training and support • Characteristics of good user-product interfaces include simplicity, ease of use, intuitive logic and organization, low memory burden, visibility, feedback, affordance, mapping and constraints. • Advantages and disadvantages of using population stereotypes for designers and users	**International-mindedness:** • Population stereotypes based on cultural expectations contribute to human error and designers must consider this when designing good user-product interfaces. **Utilization:** • Design technology topics 1 and 3 • Design technology internal assessment **Aims:** • **Aim 3:** Designers must consider the limits of population stereotypes. Through recognizing these limits, the designers can critically assess the appropriateness of their product in relation to those who will use it.

Essential idea: The designer needs to understand the reasons behind the behaviours, wants, and needs of the user.

7.3 Strategies for user research		
Nature of design: Designers should select research strategies based on the desired user experiences in the context of the product, service or system. The purpose of user research is to identify needs that reveal the complexities of personae. Real-life scenarios that simulate "actual" user experiences can generate new findings. (3.4, 3.5, 3.6)	**Concepts and principles:** • User population • Classification of users • The use of personae, secondary personae and anti-personae in user research • Scenarios provide physical and social context for different personae • Use case **Guidance:** • Users can be classified by age, gender and physical condition. • Scenarios are based on best, worst and average case.	**International-mindedness:** • User population behaviours, wants and needs may vary from one community of potential users to another, which may result in the development of a product family. **Theory of knowledge:** • Design considers the needs of individuals as paramount. Is this the case in other areas of knowledge? **Utilization:** • Design technology topics 1 and 9 • Design technology internal assessment **Aims:** • **Aim 2:** The various strategies for user research can be used by the designer to explore the true nature of a problem. Through the use of personae and use cases, the designer can build a range of possible scenarios with which to explore the problem in detail.

Essential idea: Users have a central role in evaluating whether the product meets their wants and needs.

<table>
<tr><th colspan="3">7.4 Strategies for user-centred design (UCD)</th></tr>
<tr>
<td>Nature of design:
For designers to successfully integrate usability into the design process, they require a holistic understanding of how a product, service or system is used. Designers must identify user requirements through the use of careful observation and interviews. A clear strategy for UCD will improve acceptability and usability, reducing costs and effort, while fulfilling user requirements. (1.6, 3.5)</td>
<td>Concepts and principles:
• Field research
• Method of extremes
• Observation, interviews and focus groups
• Questionnaires
• Affinity diagramming
• Participatory design, prototype and usability testing sessions
• Natural environments and usability laboratories
• Testing houses versus usability laboratories
Guidance:
• Advantages and disadvantages of different UCD strategies</td>
<td>International-mindedness:
• Testing in the environment where a product will be used is often extremely important for the design of products, especially where the problem to solve occurs in a country foreign to the design team.
Theory of knowledge:
• Is it ever possible to eliminate the effect of the observer?
• To what extent does the language used on questionnaires shape the results?
Utilization:
• Design technology topics 1, 4, 5, and 9
• Design technology internal assessment
Aims:
• Aim 9: By including potential consumers in the testing of designs and prototypes, designers gain valuable data relating to how they will interact with a product.</td>
</tr>
</table>

Essential idea: Usability is not the only factor for a designer to consider; products can be designed to evoke pleasure and emotion.

7.5 Beyond usability—designing for pleasure and emotion		
Nature of design: A designer's ability to provide satisfaction through aesthetic appeal and pleasure can greatly influence the success of a product, service or system. Understanding attitudes, expectations and motivations of consumers plays a significant role in predicting product interaction. Designers need to be empathetic and sympathetic to user emotion, which acts as a critical component to determine how he or she interprets and interacts with a product, service or system. (3.8)	**Concepts and principles:** • The four-pleasure framework: socio-pleasure, physio-pleasure, psycho-pleasure and ideo-pleasure • Design for emotion • The attract/converse/transact (ACT) model **Guidance:** • How designing for emotion can increase user engagement, loyalty and satisfaction with a product by incorporating emotion and personality • How the ACT model can be used as a framework for creating designs that intentionally trigger positive emotional responses	**Theory of knowledge:** • Are emotions purely physiological or are they culturally bound? **Utilization:** • Design technology topics 1 and 6 • Visual arts **Aims:** • **Aim 4:** The ability to express emotion through a product can not only build appeal for the consumer, but also build affinity between a product and consumer. It can enable a product to communicate how one should interact with it.

Topic 8: Sustainability

14 hours

Essential idea: Sustainable development is concerned with satisfying human needs for resources now and in the future without compromising the carrying capacity of the planet.

8.1 Sustainable development		
Nature of design: Designers utilize design approaches that support sustainable development across a variety of contexts. A holistic and systematic approach is needed at all stages of design development to satisfy all stakeholders. In order to develop sustainable products, designers must balance aesthetic, cost, social, cultural, energy, material, health and usability considerations. (2.10)	**Concepts and principles:** • Triple bottom line sustainability: environmental, economic and social • Decoupling: disconnecting economic growth and environmental impact so that one no longer depends on the other • The use of international and national laws to promote sustainable development • Sustainability reporting • Product stewardship **Guidance:** • How using resources more productively and redesigning production, it is technically possible to deliver the same or equivalent goods and services with lower environmental impact while maintaining social and equity benefits. • Consider the benefits and limitations of decoupling as an appropriate strategy for sustainability	**International-mindedness:** • Changes in governments sometimes result in the reversal of sustainable development policies leading to different approaches to international agreements. **Theory of knowledge:** • Design involves making value judgments in deciding between different ways of interacting with the environment. Is this the case in other areas of knowledge? **Utilization:** • Design technology topics 2, 4, 5, 9 and 10 • Environmental systems and societies topics 1 and 8

8.1 Sustainable development		
	• How international and national laws encourage companies to focus on something other than shareholder value and financial performance • Benefits of sustainability reporting for governments, manufacturers and consumers • Product stewardship examples include organic foods, genetically modified food, green cotton, forest stewardship and bio-plastics	**Aims:** • **Aim 9:** Triple bottom line sustainability does not only focus on the profitability of an organization or product, but also the environmental and social benefit it can bring. Organizations that embrace triple bottom line sustainability can make significant positive effects to the lives of others and the environment by changing the impact of their business activities.

Essential idea: Sustainable consumption focuses on reducing the use of resources of a product to minimize its environmental impact.

8.2 Sustainable consumption		
Nature of design: Designers develop products, services and systems that satisfy basic needs and improve quality of life. To meet sustainable consumption requirements, they must also minimize the use of natural resources, toxic materials and waste, and reduce emissions of pollutants at all stages of the life cycle. (2.10, 3.7)	**Concepts and principles:** • Consumer attitudes and behaviours towards sustainability: eco-warriors, eco-champions, eco-fans, eco-phobes • Eco-labelling and energy labelling schemes • Creating a market for sustainable products: pricing considerations, stimulating demand for green products, production of green products • Pressure groups • Lifestyle and ethical consumerism • Implications of take-back legislation for designers, manufacturers and consumers **Guidance:** • Consider eco-labelling and energy labelling schemes from different country contexts • Advantages and disadvantages of consumer and environmental pressure groups for the user, manufacturer and designer • How pressure groups exert influence for changes on these issues and support or undermine development of specific technologies	**International-mindedness:** • There are many different eco-labelling and energy-labelling schemes across the world that could be standardized. **Theory of knowledge:** • Eco-warriors sometimes break laws to express their views. Does the rightness or wrongness of an action depend on the situation? **Utilization:** • Design technology topics 2, 4, 5 and 10 • Economics topic 1 • Environmental systems and societies topic 1 **Aims:** • **Aim 5:** It is not only the role of designers to create markets for sustainable products. Consumers need to change their habits and express a want and need for these products.

8.2 Sustainable consumption		
	• How consumer and environmental pressure groups can attract widespread support using the media (including social media) • How consumers have become increasingly aware of information provided by pressure groups and as markets have globalized, so has consumer power • Consider strategies for managing western consumption while raising the standard of living of the developing world without increasing resource use and environmental impact	

Essential idea: Sustainable design is a philosophy of developing products in line with social, economic, and ecological sustainability principles.

8.3 Sustainable design

Nature of design:

The first step to sustainable design is to consider a product, service or system in relation to eco-design and analyse its impact using life cycle analysis. The designer then develops these to minimize environmental impacts identified from this analysis. Considering sustainability from the beginning of the process is essential. (2.8)

Concepts and principles:

- Green design versus sustainable design
- Datschefski's five principles of sustainable design: cyclic, solar, safe, efficient, social

Guidance:

- The differences between green design and sustainable design
- Comparison of timescale between green design and sustainable design

International-mindedness:

- The application of Datschefski's social principle of sustainable design can have different effects across different countries.

Theory of knowledge:

- Datschefski developed his five principles of sustainable design to help designers structure their approach and thoughts. In what ways and areas would the absence of experts most severely limit our knowledge?

Utilization:

- Design technology topics 1, 2, 4, 5 and 10

Aims:

- **Aim 10:** Datschefski's five principles of sustainable design equip the designer with a tool not only to design new products, but also to evaluate an existing product. This can lead to new design opportunities and increase the level at which a product aligns with these principles.

Essential idea: Sustainable innovation facilitates the diffusion of sustainable products and solutions into the marketplace.

8.4 Sustainable innovation		
Nature of design: Sustainable innovation yields both bottom line and top line returns as developing products, services and systems that are environmentally friendly lowers costs through reducing the resources required. Designers should view compliance with government legislation as an opportunity for sustainable innovation. (2.9)	**Concepts and principles:** • Complexity and timescale of sustainable innovation • Top-down strategies • Bottom-up strategies • Government intervention in innovation • Macro energy sustainability • Micro energy sustainability • Energy security **Guidance:** • Examples of top-down and bottom-up strategies and the advantages and disadvantages for consumers/users • Government intervention includes regulation, education, taxes and subsidies • How macro energy sustainability can be influenced through international treaties and energy policies, instruments for change and disincentives, and national systems changing policy when government leadership changes • How micro energy sustainability can be influenced by the role of the government in raising awareness and changing attitudes, and promotion of individual and business action towards energy sustainability • How energy security can be influenced by energy demand/supply trends and forecasting, demand response versus energy efficiency, and smart grids	**International-mindedness:** • The internal policies of particular governments have international implications. **Theory of knowledge:** • To what extent should environmental concerns limit our pursuit of knowledge? **Utilization:** • Design technology topics 2, 4, 5 and 10 • Environmental systems and societies topic 1 **Aims:** • **Aim 1:** As energy security becomes an ever more important issue for all countries, designers, engineers and inventors need to develop new ways of efficiently generating energy. As new energy production technologies become available, designers need to harness them to be used in new products to improve their energy efficiency.

Topic 9: Innovation and markets

13 hours

Essential idea: Companies and businesses can utilize a range of different strategies to develop products, services and systems.

9.1 Corporate strategies		
Nature of design: The success of a company relies heavily on the strategies it adopts. The evaluation of products, strategies and systems can inform the selection of the most appropriate strategies to follow that will enable a company to achieve its objectives. (1.12)	**Concepts and principles:** • Pioneering strategy • Imitative strategy • Market development • Product development • Market penetration • Product diversification • Hybrid approaches • The relative success of pioneering and innovative strategies • Corporate social responsibility **Guidance:** • Comparison of success between pioneering and imitative strategies • Examples of companies and products that have used the above strategies • Examples of a company and its products that are a result of a hybrid approach	**International-mindedness:** • Adoption of corporate social responsibility by multinational companies can be used as a distraction from their core business practices. **Theory of knowledge:** • Is strategic planning more influenced by reason, intuition or imagination? Or by a combination of all of the ways of knowing? **Utilization:** • Design technology topics 3, 5, 7, 8 and 10 • Business management topic 1 • Economics topic 1 **Aims:** • **Aim 5:** The designer must consider the ethical implications of imitating the products of others and their implications on a cultural, economic, and intellectual property level.

9.1 Corporate strategies		
	• How corporate social responsibility may be a particular goal of a company whereby the aim is to manage the economic, social and environmental impacts of their operation to maximize the benefits and minimize the disadvantages • Examples of evidence of effective corporate social responsibility for a major multinational company	

Essential idea: Designers must research and consider the target market sectors and segments in the design of their products.

9.2 Market sectors and segments		
Nature of design: Designers must consider the market when targeting their product, service or system. The smaller the sector, the more the target audience will have in common. Companies may decide to compete in the whole market or only in segments that are attractive and/or familiar. A designer's understanding of the identified market is essential. (2.6)	**Concepts and principles:** • Categories of market sectors • The influence of market sectors • Classifications of consumer market segments: income, profession, age, family, values, behaviour • The development of a product family **Guidance:** • Broad categories of market sectors include geographical sectors focusing on values, culture and characteristics of purchasers in a particular region and purchasing power; client-based sectors focusing on consumers, industrial, public sector and commercial • How companies take into account market sectors in the design and manufacture of products • Examples of products designed for only one sector and products designed to be sold to more than one sector • How the needs of the markets segments listed impact on the design of products and scale of production • Examples of product families	**International-mindedness:** • Two broad categories of market sectors are geographical- and client-based, with specific segments varying greatly. **Theory of knowledge:** • Gaining information on market sectors often employs many of the methods of gaining knowledge most closely associated with the human sciences. What are these methods of gaining knowledge, and how do they compare to the methods used in the natural sciences? **Utilization:** • Design technology topics 5 and 7 • Design technology internal assessment • Business management topic 4 **Aims:** • **Aim 6:** By identifying the market sectors and segments a product will be designed for, a designer can gain data directly from the perspective of the potential consumer.

Essential idea: The marketing mix is often crucial when determining a product or brand's offering.

9.3 Marketing mix		
Nature of design: Empathy for, and understanding of the target audience is developed through thorough analysis of the market chosen. This informs several factors: the standards that end users demand; how and where to distribute and sell the product; how much they are willing to pay for a certain product and its quality; and how to communicate the launch of a product. Correct analysis of these factors could determine the success or failure of a product, despite its quality. (3.8)	**Concepts and principles:** • Marketing mix—the 4Ps: product, place, price, promotion • Product: standardization of products • Place: implications of internet selling for a company in relation to its supply chain and distribution network • Strategies of setting price: cost-plus, demand pricing, competitor-based pricing, product line pricing, psychological pricing • Promotion: advertising, publicity, personal selling **Guidance:** • Consider government standards for a particular market segment, component standardization and industry-wide standards • Examples of trigger products and incremental products • Analysis of product pricing that matches each of the price setting strategies • Examples of promotion campaigns for different products	**International-mindedness:** • When developing marketing campaigns, companies take account of different cultures and sectors in the target market. **Theory of knowledge:** • Some advertisers emphasize the "science" behind their products. Does this suggest that some people may see scientific knowledge as being more reliable than knowledge in other areas of knowledge? **Utilization:** • Design technology topics 2, 8 and 10 • Business management topic 4 **Aims:** • **Aim 7:** Marketing is often a new area for designers to consider. Exploring unfamiliar aspects of innovation improves their understanding of the market needs of the products they are designing.

Essential idea: Market research is any organized effort to gather information about markets or customers.

9.4 Market research		
Nature of design: Market research often identifies how to improve the product, service or system and increase its chance of success within a particular sector or segment. The price a user is prepared to pay is usually determined through market research. This in turn sets an upper limit of cost to the design and production of a potential product, service or system. Market research has a crucial role in determining the constraints a designer has to work within. (1.5)	**Concepts and principles:** • Purpose of market research • Consumers' reaction to technology and green design, and subsequent impact on design development and market segmentation • Market research strategies **Guidance:** • The purpose of market research includes idea generation and development; evaluating market potential and economic trends; collecting data relating to demographics, family roles, consumers; identifying suitable promotional strategies; considering technological trends and scientific advances • Market research strategies include literature search, expert appraisal, user trial, user research, perceptual mapping and environmental scanning • Advantages and disadvantages of each market research strategy considering the nature, reliability and cost of the research and importance to the design development process	**International-mindedness:** • Determining the purpose of market research allows designers to clearly identify who needs to be included and their differing requirements. **Theory of knowledge:** • What are the assumptions that underlie methods used to gain knowledge in this area? **Utilization:** • Design technology topics 5 and 7 • Design technology internal assessment • Business management topic 4 **Aims:** • **Aim 1:** Often designers will work on projects that have new and radically unfamiliar contexts. This will deepen their understanding of market research, equipping them with a range of tools and skills that they can employ in many areas of life and empowering them as lifelong learners.

Essential idea: Branding creates an identity for a product or company, which makes it distinct from another and can provide added value.

9.5 Branding		
Nature of design: In order to diffuse products into the marketplace, the identity of a company is typically embodied in a brand. The brand is communicated to the consumer through a value proposition. Designers help to communicate this by: building a strong user experience around the brand identity; determining content design; establishing the tone of message through advertisements; promotion. (3.9)	**Concepts and principles:** • Brand loyalty • How brands appeal to different market segments • The difference between a trademark and registered design • The implications for a company of positive and negative publicity on brand image • Contribution of packaging to brand identity • Effects of product branding • Evaluating the global impact of branding **Guidance:** • Examples of positive and negative effects of product branding on different market segments • Examples of products affected by branding on a global scale	**International-mindedness:** • A globally recognized and appealing brand allows organizations and companies to engage with global markets. This raises ethical issues with some products. **Utilization:** • Design technology topics 3, 5 and 6 • Business management topic 4 **Aims:** • **Aim 4:** A brand encapsulates the identity of a company and its products. The brand designer needs to ensure that the message of a company is communicated clearly and creatively to allow them to stand out from the competition.

Topic 10: Commercial production

15 hours

Essential idea: Just in time and just in case are opposing production strategies utilized by the manufacturer.

10.1 Just in time (JIT) and just in case (JIC)		
Nature of design: While inventory creates a safety net for companies, maintenance and potential waste of resources can have significant implications for companies and the environment. Manufacturers must evaluate and analyse each market and determine whether a JIT or JIC strategy is the best to follow. (2.7)	**Concepts and principles:** • Just in case (JIC) • Just in time (JIT) **Guidance:** • Advantages and disadvantages of JIC and JIT	**International-mindedness:** • Effective business processes and practices developed in some countries have been exported successfully. **Theory of knowledge:** • Manufacturers decide whether to pursue JIT or JIC as a production strategy depending on their perception of where the market is going. To what extent do different areas of knowledge incorporate doubt as a part of their methods? **Utilization:** • Design technology topic 4 • Business management topic 5 **Aims:** • **Aim 2:** An in-depth knowledge and understanding of the potential success of a product can lead manufacturers to decide in favour of JIC or JIT. This can vary from one product to the next and requires experience and intuition.

Essential idea: Lean production aims to eliminate waste and maximize the value of a product based on the perspective of the consumer.

10.2 Lean production		
Nature of design: Lean production considers product and process design as an ongoing activity and not a one-off task, and should be viewed as a long-term strategy. (3.5)	**Concepts and principles:** • Characteristics of lean production • Principles of lean production • Value stream mapping • Workflow analysis • Product family • Role of the workforce • Kaizen • Lead time • The 5 Ss: sorting, stabilizing, shining, standardizing, sustaining the practice • The 7 wastes: overproduction, waiting, transporting, inappropriate processing, unnecessary inventory, unnecessary/excess motion, defects **Guidance:** • Characteristics of lean production include JIT supplies; highly trained multi-skilled workforce; quality control and continuous improvement; zero defects, zero inventory • Principles of lean production include: eliminating waste; minimizing inventory; maximizing flow; pulling production from customer demand; meeting customer requirements; doing it right first time; empowering workers; designing for rapid changeover; partnering with suppliers; creating a culture of continuous improvement (kaizen)	**International-mindedness:** • The implementation of lean production has benefits for the global environment. **Theory of knowledge:** • The importance of the individual is recognized in design processes. Is this the case in other areas of knowledge? **Utilization:** • Design technology topics 2, 4, 5 and 8 • Environmental systems and societies topic 1 **Aims:** • **Aim 9:** The role of the workforce in lean production is paramount, relying on their wisdom and experience to improve the process, reducing waste, cost and production time. Recognizing this results in motivated workforces whose interests are in the success of the product.

10.2 Lean production		
	• The role of the workforce includes training, devolution in power relating to process improvement and kaizen • Consider the contribution of value stream mapping and workflow analysis to the design of an effective lean production method • Advantages and disadvantages of lean production	

Essential idea: Computer-integrated manufacturing uses computers to automatically monitor and control the entire production of a product.

<table>
<tr><th colspan="3">10.3 Computer integrated manufacturing (CIM)</th></tr>
<tr>
<td>Nature of design:

When considering design for manufacture (DfM), designers should be able to integrate computers from the earliest stage of design. This requires knowledge and experience of the manufacturing processes available to ensure integration is efficient and effective. Through the integration of computers, the rate of production can be increased and errors in manufacturing can be reduced or eliminated, although the main advantage is the ability to create automated manufacturing processes. (1.16)</td>
<td>Concepts and principles:

• Elements of CIM: design, planning, purchasing, cost accounting, inventory control, distribution
• CIM and scales of production

Guidance:

• Advantages and disadvantages of CIM in relation to initial investment and maintenance
• Advantages and disadvantages of CIM in relation to different production systems</td>
<td>International-mindedness:

• A CIM system allows for efficient global workflow and distribution.

Theory of knowledge:

• Technology has a profound influence in design. How have other areas of knowledge been influenced by technology?

Utilization:

• Design technology 4 and 8

Aims:

• Aim 8: The integration of computer control into manufacturing can streamline systems, negating the need for time-consuming activities, such as stocktaking, but also reducing the size of the workforce.</td>
</tr>
</table>

Essential idea: Quality management focuses on producing products of consistent required quality.

10.4 Quality management		
Nature of design: Designers should ensure that the quality of products is consistent through development of detailed manufacturing requirements. They also need to focus on the means to achieve it. The importance of quality management through quality control (QC), statistical process control (SPC) and quality assurance (QA) reduces the potential waste of resources. (1.5)	**Concepts and principles:** • Quality control (QC) • Statistical process control (SPC) • Quality assurance (QA) **Guidance:** • How QC at source eliminates waste from defects • How continuous monitoring ensures that machines perform to the pre-determined standard/quality • How QC, SPC and QA contribute to quality management • The differences between QC, SPC and QA	**International-mindedness:** • Effective quality management can have major benefits for the environment. **Theory of knowledge:** • There are commonly accepted ways of assuring quality in design. How do other areas of knowledge ensure the quality of their outputs? **Utilization:** • Design technology topics 2, 3, 4, 5 and 8 • Design technology internal assessment • Business management topic 5 **Aims:** • **Aim 3:** The implementation of quality management strategies requires a critical and complete understanding of the needs of a product. To ensure efficiency and efficacy, these measures need to be designed into the product and its production system.

Essential idea: Designers must consider the economic viability of their designs for them to gain a place in the market.

10.5 Economic viability		
Nature of design: Designers need to consider how the costs of materials, manufacturing processes, scale of production and labour contribute to the retail cost of a product. Strategies for minimizing these costs at the design stage are most effective to ensure that a product is affordable and can gain a financial return. (1.15)	**Concepts and principles:** • Cost-effectiveness • Value for money • Costing versus pricing: fixed costs, variable costs, cost analysis, break-even • Pricing strategies: price-minus strategy, retail price, wholesale price, typical manufacturing price, target costs, return on investment, unit cost, sales volume, financial return **Guidance:** • The relationship between what a product is worth and how much it costs • Calculation of prices based on the listed pricing strategies	**International-mindedness:** • The cost effectiveness of a product can determine whether it can enter economically diverse national and international markets. **Theory of knowledge:** • The retail price of a product is partly based on evidence of its potential position in the market. What counts as evidence in various areas of knowledge? **Utilization:** • Design technology topics 2, 4, 5 and 9 • Design technology internal assessment • Economics topic 1 **Aims:** • **Aim 7:** The economic viability of a product is paramount for designers if they are to get their product into production. Understanding how to design a product to specification, at lowest cost and to the appropriate quality while giving added value, can determine the relationship between what a product is worth and how much it costs.

Assessment in the Diploma Programme

General

Assessment is an integral part of teaching and learning. The most important aims of assessment in the Diploma Programme are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessments are used in the Diploma Programme. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- Formative assessment informs both teaching and learning. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.
- Summative assessment gives an overview of previous learning and is concerned with measuring student achievement.

The Diploma Programme primarily focuses on summative assessment designed to record student achievement at, or towards the end of, the course of study. However, many of the assessment instruments can also be used formatively during the course of teaching and learning, and teachers are encouraged to do this. A comprehensive assessment plan is viewed as being integral with teaching, learning and course organization. For further information, see the IB *Programme standards and practices* (2010) document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the Diploma Programme please refer to the publication *Diploma Programme assessment: Principles and practice* (2009).

To support teachers in the planning, delivery and assessment of the Diploma Programme courses, a variety of resources can be found on the OCC or purchased from the IB store (http://store.ibo.org). Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the OCC. Past examination papers as well as markschemes can be purchased from the IB store.

Methods of assessment

The IB uses several methods to assess work produced by students.

Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do, and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses.

Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

Analytic markschemes

Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response.

Marking notes

For some assessment components marked using assessment criteria, marking notes are provided. Marking notes give guidance on how to apply assessment criteria to the particular requirements of a question.

Inclusive assessment arrangements

Inclusive assessment arrangements are available for candidates with assessment access requirements. These arrangements enable candidates with diverse needs to access the examinations and demonstrate their knowledge and understanding of the constructs being assessed.

The IB document *Candidates with assessment access requirements* provides details on all the inclusive assessment arrangements available to candidates with learning support requirements. The IB document *Learning diversity in the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes* outlines the position of the IB with regard to candidates with diverse learning needs in the IB programmes. For candidates affected by adverse circumstances, the IB documents *General regulations: Diploma Programme* (2011) and the *Handbook of procedures for the Diploma Programme* provide details on access consideration.

Responsibilities of the school

The school is required to ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity in the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes*.

Assessment outline—SL

First assessment 2016

Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)
		1+2	3	
Paper 1	30	30		¾
Paper 2	30	12	18	1½
Internal assessment Design project	40	All assessment objectives are tested equally		40

Assessment outline—HL

First assessment 2016

Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)
		1+2	3	
Paper 1	20	20		1
Paper 2	20	8	12	1½
Paper 3	20	10	10	1½
Internal assessment Design project	40	All assessment objectives are tested equally		60

External assessment

The method used to assess students is through detailed markschemes specific to each examination paper (except paper 1, multiple-choice).

External assessment details—SL

Paper 1

Duration: ¾ hour
Weighting: 30%
Marks: 30

- 30 multiple-choice questions on the core material.
- The questions on paper 1 test assessment objectives 1 and 2.
- The use of calculators is not permitted.
- No marks are deducted for incorrect answers.

Paper 2

Duration: 1½ hours
Weighting: 30%
Marks: 50

- Section A: one data-based question and several short-answer questions on the core material (all compulsory). Maximum of 30 marks.
- Section B: one extended-response question on the core material (from a choice of three). Maximum of 20 marks.
- The questions on paper 2 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- This paper is common with HL paper 2.

External assessment details—HL

Paper 1

Duration: 1 hour
Weighting: 20%
Marks: 40

- 40 multiple-choice questions on the core and HL extension material.
- The questions on paper 1 test assessment objectives 1 and 2.
- The use of calculators is not permitted.
- No marks are deducted for incorrect answers.

Paper 2

Duration: 1½ hours
Weighting: 20%
Marks: 50

- Section A: one data-based question and several short-answer questions on the core material (all compulsory). Maximum of 30 marks.
- Section B: one extended-response question on the core material (from a choice of three). Maximum of 20 marks.
- The questions on paper 2 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- This paper is common with SL paper 2.

Paper 3

Duration: 1½ hours
Weighting: 20%
Marks: 40

- Section A: two structured questions on the HL extension material, both compulsory and each worth a maximum of 10 marks.
- Section B: one structured question on the HL extension material based on a case study. Maximum of 20 marks.
- The use of calculators is permitted. (See calculator section on the OCC.)

Internal assessment

Purpose of internal assessment

Internal assessment is an integral part of the course and is compulsory for both SL and HL students. It enables students to demonstrate the application of their skills and knowledge, and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught.

The internal assessment requirements at SL and at HL are different. The first four assessment criteria (A–D) are common between SL and HL; however, HL design projects have additional requirements, which are assessed using two additional criteria (E and F). This internal assessment section of the guide should be read in conjunction with the internal assessment section of the teacher support material.

Guidance and authenticity

The work submitted for internal assessment must be the student's own work. However, it is not the intention that students should decide upon a title or topic and be left to work on the internal assessment component without any further support from the teacher. The teacher should play an important role during both the planning stage and the period when the student is working on the internally assessed work. It is the responsibility of the teacher to ensure that students are familiar with:

- the requirements of the type of work to be internally assessed
- the IB animal experimentation policy
- the assessment criteria; students must understand that the work submitted for assessment must address these criteria effectively.

Teachers and students must discuss the internally assessed work. Students should be encouraged to initiate discussions with the teacher to obtain advice and information, and students must not be penalized for seeking guidance. As part of the learning process, teachers should read and give advice to students on one draft of the work. The teacher should provide oral or written advice on how the work could be improved, but not edit the draft. The next version handed to the teacher must be the final version for submission.

It is the responsibility of teachers to ensure that all students understand the basic meaning and significance of concepts that relate to academic honesty, especially authenticity and intellectual property. Teachers must ensure that all student work for assessment is prepared according to the requirements and must explain clearly to students that the internally assessed work must be entirely their own. Where collaboration between students is permitted, it must be clear to all students what the difference is between collaboration and collusion.

All work submitted to the IB for moderation or assessment must be authenticated by a teacher, and must not include any known instances of suspected or confirmed academic misconduct. Each student must confirm that the work is his or her authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work it cannot be retracted. The requirement to confirm the authenticity of work applies to the work of all students, not just the sample work that will be submitted to the IB for the purpose of moderation. For further details refer to the IB publication *Academic honesty* (2011), *The Diploma Programme: From principles into practice* (2009) and the relevant articles in *General regulations: Diploma Programme* (2011).

Authenticity may be checked by discussion with the student on the content of the work, and scrutiny of one or more of the following:

- the student’s initial proposal
- the first draft of the written work
- the references cited
- the style of writing compared with work known to be that of the student
- the analysis of the work by a web-based plagiarism detection service such as http://www.turnitin.com.

The same piece of work cannot be submitted to meet the requirements of both the internal assessment and the extended essay.

Group work

Each design project is an individual piece of work based on different research collected.

It should be made clear to students that all work connected with the writing of the design project, should be their own. It is therefore helpful if teachers try to encourage in students a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work.

Time allocation

Internal assessment is an integral part of the design technology course, contributing 40% to the final assessment in the SL and the HL courses. This weighting should be reflected in the time that is allocated to teaching the knowledge, skills and understanding required to undertake the work, as well as the total time allocated to carry out the work.

It is recommended that a total of approximately 40 hours (SL) and 60 hours (HL) should be allocated to the work. This should include:

- time for the teacher to explain to students the requirements of the internal assessment
- class time for students to work on the internal assessment component and ask questions
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

Safety requirements and recommendations

While teachers are responsible for following national or local guidelines, which may differ from country to country, attention should be given to the guidelines below, which were developed for the International Council of Associations for Science Education (ICASE) Safety Committee by The Laboratory Safety Institute (LSI).

It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

The Laboratory Safety Institute's Laboratory Safety Guidelines ...

40 suggestions for a safer lab

Steps Requiring Minimal Expense

1. Have a written health, safety and environmental affairs (HS&E) policy statement.
2. Organize a departmental HS&E committee of employees, management, faculty, staff and students that will meet regularly to discuss HS&E issues.
3. Develop an HS&E orientation for all new employees and students.
4. Encourage employees and students to care about their health and safety and that of others.
5. Involve every employee and student in some aspect of the safety program and give each specific responsibilities.
6. Provide incentives to employees and students for safety performance.
7. Require all employees to read the appropriate safety manual. Require students to read the institution's laboratory safety rules. Have both groups sign a statement that they have done so, understand the contents, and agree to follow the procedures and practices. Keep these statements on file in the department office
8. Conduct periodic, unannounced laboratory inspections to identify and correct hazardous conditions and unsafe practices. Involve students and employees in simulated OSHA inspections.
9. Make learning how to be safe an integral and important part of science education, your work, and your life.
10. Schedule regular departmental safety meetings for all students and employees to discuss the results of inspections and aspects of laboratory safety.
11. When conducting experiments with hazards or potential hazards, ask yourself these questions:
    - What are the hazards?
    - What are the worst possible things that could go wrong?
    - How will I deal with them?
    - What are the prudent practices, protective facilities and equipment necessary to minimize the risk of exposure to the hazards?
12. Require that all accidents (incidents) be reported, evaluated by the departmental safety committee, and discussed at departmental safety meetings.
13. Require every pre-lab/pre-experiment discussion to include consideration of the health and safety aspects.
14. Don't allow experiments to run unattended unless they are failsafe.
15. Forbid working alone in any laboratory and working without prior knowledge of a staff member.
16. Extend the safety program beyond the laboratory to the automobile and the home.
17. Allow only minimum amounts of flammable liquids in each laboratory.
18. Forbid smoking, eating and drinking in the laboratory.
19. Do not allow food to be stored in chemical refrigerators.

20. Develop plans and conduct drills for dealing with emergencies such as fire, explosion, poisoning, chemical spill or vapour release, electric shock, bleeding and personal contamination.
21. Require good housekeeping practices in all work areas.
22. Display the phone numbers of the fire department, police department, and local ambulance either on or immediately next to every phone.
23. Store acids and bases separately. Store fuels and oxidizers separately.
24. Maintain a chemical inventory to avoid purchasing unnecessary quantities of chemicals.
25. Use warning signs to designate particular hazards.
26. Develop specific work practices for individual experiments, such as those that should be conducted only in a ventilated hood or involve particularly hazardous materials. When possible most hazardous experiments should be done in a hood.

Steps Requiring Moderate Expense

27. Allocate a portion of the departmental budget to safety.
28. Require the use of appropriate eye protection at all times in laboratories and areas where chemicals are transported.
29. Provide adequate supplies of personal protective equipment—safety glasses, goggles, face shields, gloves, lab coats and bench top shields.
30. Provide fire extinguishers, safety showers, eye wash fountains, first aid kits, fire blankets and fume hoods in each laboratory and test or check monthly.
31. Provide guards on all vacuum pumps and secure all compressed gas cylinders.
32. Provide an appropriate supply of first aid equipment and instruction on its proper use.
33. Provide fireproof cabinets for storage of flammable chemicals.
34. Maintain a centrally located departmental safety library:
    - "Safety in School Science Labs", Clair Wood, 1994, Kaufman & Associates, 101 Oak Street, Wellesley, MA 02482
    - "The Laboratory Safety Pocket Guide", 1996, Genium Publisher, One Genium Plaza, Schnectady, NY
    - "Safety in Academic Chemistry Laboratories", ACS, 1155 Sixteenth Street NW, Washington, DC 20036
    - "Manual of Safety and Health Hazards in The School Science Laboratory", "Safety in the School Science Laboratory", "School Science Laboratories: A Guide to Some Hazardous Substances", Council of State Science Supervisors (now available only from LSI)
    - "Handbook of Laboratory Safety", 4th Edition, CRC Press, 2000 Corporate Boulevard NW, Boca Raton, FL 33431
    - "Fire Protection Guide on Hazardous Materials", National Fire Protection Association, Batterymarch Park, Quincy, MA 02269
    - "Prudent Practices in the Laboratory: Handling and Disposal of Hazardous Chemicals", 2nd Edition, 1995
    - "Biosafety in the Laboratory", National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418
    - "Learning By Accident", Volumes 1–3, 1997–2000, The Laboratory Safety Institute, Natick, MA 01760

    (All are available from **LSI**.)

35. Remove all electrical connections from inside chemical refrigerators and require magnetic closures.

36. Require grounded plugs on all electrical equipment and install ground fault interrupters (GFIs) where appropriate.

37. Label all chemicals to show the name of the material, the nature and degree of hazard, the appropriate precautions, and the name of the person responsible for the container.

38. Develop a program for dating stored chemicals and for recertifying or discarding them after predetermined maximum periods of storage.

39. Develop a system for the legal, safe and ecologically acceptable disposal of chemical wastes.

40. Provide secure, adequately spaced, well ventilated storage of chemicals.

The Laboratory Safety Institute

Using assessment criteria for internal assessment

For internal assessment, a number of assessment criteria have been identified. Each assessment criterion has level descriptors describing specific achievement levels, together with an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Teachers must judge the internally assessed work at SL and at HL against the criteria using the level descriptors.

- There are four common criteria used to assess both SL and HL; however, HL is assessed using two additional criteria.
- The aim is to find, for each criterion, the descriptor that conveys most accurately the level attained by the student, using the best-fit model. A best-fit approach means that compensation should be made when a piece of work matches different aspects of a criterion at different levels. The mark awarded should be one that most fairly reflects the balance of achievement against the criterion. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.
- When assessing a student's work, teachers should read the level descriptors for each criterion until they reach a descriptor that most appropriately describes the level of the work being assessed. If a piece of work seems to fall between two descriptors, both descriptors should be read again and the one that more appropriately describes the student's work should be chosen.
- Where there are two or more marks available within a level, teachers should award the upper marks if the student's work demonstrates the qualities described to a great extent; the work may be close to achieving marks in the level above. Teachers should award the lower marks if the student's work demonstrates the qualities described to a lesser extent; the work may be close to achieving marks in the level below.
- Only whole numbers should be recorded; partial marks (fractions and decimals) are not acceptable.
- Teachers should not think in terms of a pass or fail boundary, but should concentrate on identifying the appropriate descriptor for each assessment criterion.

- The highest level descriptors do not imply faultless performance but should be achievable by a student. Teachers should not hesitate to use the extremes if they are appropriate descriptions of the work being assessed.
- A student who attains a high achievement level in relation to one criterion will not necessarily attain high achievement levels in relation to the other criteria. Similarly, a student who attains a low achievement level for one criterion will not necessarily attain low achievement levels for the other criteria. Teachers should not assume that the overall assessment of the students will produce any particular distribution of marks.
- It is recommended that the assessment criteria be made available to students.

Practical work and internal assessment

General introduction

The internal assessment (IA) requirement is worth 40% of the final assessment and consists of one design project.

Student work is internally assessed by the teacher and externally moderated by the IB. The performance in IA at both SL and HL is marked against 4 common assessment criteria, with an additional 2 assessment criteria for HL.

The expectations at SL and HL for the 4 common assessment criteria are the same.

The IA task consists of one design project. At SL, this project will be completed in about 40 hours. At HL, this project will be completed in about 60 hours. Each criterion should be addressed in about 10 hours.

Clarifications follow each assessment criterion with further detail of what is expected for each strand of the criterion. Indications of the scope and size of the sections of each project can be found in the clarifications. These amount to approximately 34 A4 pages (or equivalent) at SL and 44 A4 pages (or equivalent) at HL. The maximum page limit at SL is 38 A4 pages (or equivalent). The maximum page limit at HL is 50 A4 pages (or equivalent). These limits should be made clear to the students. The teacher should not award any marks for work on pages over this limit. If selected in the sample for moderation, the examiner will stop reading the project at this limit.

The 4 common assessment criteria are mirrored by the stages of the design cycle, which focuses on invention. The additional two criteria used for HL only extend the scope of the design cycle to include aspects of innovation.

The design project allows a wide range of contexts to be explored through the varying material disciplines of design technology, including product design, food product design, fashion design/textiles, electronic product design, robotics, and so on. The design project addresses many of the learner profile attributes as well.

The task produced should be complex and commensurate with the level of the course. It should require a purposeful research question and the rationale for it. The marked exemplar material produced in the teacher support material demonstrates that the assessment will be rigorous and of the same standard as the assessment in the previous courses.

Exemplars of a range of design contexts appear in the teacher support material.

The assessment criteria are detailed in the following section and are all assessed using a 9 point scale.

Internal assessment details

SL IA component

Duration: 40 hours
Weighting: 40%

- Individual design project
- This design project covers assessment objectives 1, 2, 3 and 4.
- At SL, the design project is assessed against the 4 common criteria:
  - Criterion A: Analysis of a design opportunity
  - Criterion B: Conceptual design
  - Criterion C: Development of a detailed design
  - Criterion D: Testing and evaluation

HL IA component

Duration: 60 hours
Weighting: 40%

- Individual design project
- This design project covers assessment objectives 1, 2, 3 and 4.
- At HL, the design project is assessed against the 4 common criteria and 2 HL only criteria:
  - Criterion A: Analysis of a design opportunity
  - Criterion B: Conceptual design
  - Criterion C: Development of a detailed design
  - Criterion D: Testing and evaluation
  - Criterion E: Commercial production
  - Criterion F: Marketing strategies

Internal assessment criteria—Common to SL and HL

Criterion A: Analysis of a design opportunity

Clients and designers establish a design opportunity before engaging with the design process. Establishing the design opportunity often stems from a real-life problem, which needs to be solved. By investigating this problem and design opportunity thoroughly, designers can gain clear direction in the requirements for a product. To meet the requirements of this criterion, students must:

- describe a problem which leads to a design opportunity
- investigate the problem to develop a design brief
- develop marketing and design specifications.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **identifies** a problem • **states** the key findings from relevant market and user research • develops a simple brief, which identifies **few** relevant parameters of the problem • develops a marketing specification, which **states** the requirements • develops a design specification, which **states** the requirements.
4–6	The student: • **identifies** an appropriate problem, which leads to a design opportunity • **describes** the key findings from relevant market and user research • develops a brief, which identifies **some** of the relevant parameters of the problem • develops a marketing specification, which **outlines** the requirements • develops a design specification, which **outlines** the requirements.
7–9	The student: • **describes** an appropriate problem, which leads to a design opportunity • **explains** the key findings from relevant market and user research • develops a **detailed** brief, which identifies the relevant parameters of the problem • develops a marketing specification, which **justifies** the requirements • develops a design specification, which **justifies** the requirements.

Clarifications

Describes an appropriate problem, which leads to a design opportunity
The design problem should be clearly stated using supporting materials, which may include: • photographs • extracts from letters, magazines and news articles • summarized results from questionnaires or interviews. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Explains the key findings from relevant market and user research
The key findings should be provided in a summative form that shows evidence of: • quantitative and qualitative data collected using a range of techniques and appropriate primary and secondary sources • an analysis of competing or similar products. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Develops a detailed brief which identifies the relevant parameters of the problem

A design brief comprises the expected outcome and broad requirements determined from the market and user research. The feasibility of the project should also be considered.

The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.

Develops a marketing specification, which justifies the requirements

Marketing specifications relate to market and user characteristics of the proposed design.

- Target market—Consideration only needs to be given to market sectors and segments.
- Target audience—Differentiate between the target market and the target audience. Characteristics of the users should be established.
- Market analysis—A summary is required of the important information gathered about potential users and the market. An appraisal of economic viability of the proposed design from a market perspective is important taking into account fixed and variable costs and pricing.
- User need—Specifications should identify the essential requirements that the product must satisfy in relation to market and user need.
- Competition—A thorough analysis of competing designs is required to establish the market need.

The marketing specification must be developed from the design brief and research.

The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.

Develops a design specification, which justifies the requirements

A design specification details:

- aesthetic requirements
- cost constraints
- customer requirements
- environmental requirements
- size constraints
- safety considerations
- performance requirements and constraints
- materials requirements
- manufacturing requirements.

All of the requirements, constraints and considerations must be specific, feasible and measureable.

The design specification must be developed from the design brief and research.

The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.

Criterion B: Conceptual design

Once the design brief and specifications have been established, designers explore a range of possible concepts through modelling. As the concepts are developed and refined, their feasibility is determined against the specifications, which helps determine the most appropriate ideas to take forward into detailed design development. Students will use concept modelling to develop ideas to meet appropriate specifications, which explore solutions to the problem and justify the most appropriate idea for detailed development.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • demonstrates **limited** development of **few** ideas, which explore solutions to the problem • selects the most appropriate idea for detailed development **with no justification**.
4–6	The student: • develops ideas with reference to the specifications, which explore solutions to the problem • uses concept modelling **with limited analysis** • selects the most appropriate idea for detailed development **with limited justification**.
7–9	The student: • develops **feasible** ideas to meet appropriate specifications, which explore solutions to the problem • uses concept modelling **to guide design development** • **justifies** the most appropriate idea for detailed development.

Clarifications

Develops ideas to meet appropriate specifications which explore solutions to the problem
Ideas must be **developed** and **refined** to enable a decision to be made about the preferred design to be developed in detail. This must include: • generating original ideas • selecting ideas to incrementally improve them to meet appropriate specifications • communicating ideas clearly using appropriate techniques • annotation to identify key features and explain how they meet the design specifications • undertaking additional research as required to inform development. The evidence for achievement against this strand should be presented in approximately six A4 pages or the equivalent.

Uses concept modelling to guide design development
Concept models in the form of sketches, CAD, 2D and 3D models should be used to establish the validity of ideas against specifications before refining ideas through detailed development. Concept modelling is used to: • test design ideas to find out if they will meet requirements • provide feedback, which is used to develop designs further. Students should consider the appropriate use of conceptual, graphical, physical and CAD models to develop, refine and test their ideas. The evidence for achievement against this strand should be presented in approximately four A4 pages or the equivalent.
Justifies the most appropriate idea for detailed development
The most appropriate idea should be validated against specifications before development is refined to enable manufacture. • Evaluate ideas and models against the design specification to identify the most feasible solution. • Present the most feasible idea. The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.

Criterion C: Development of a detailed design

The designer needs to refine the concept design chosen further and detail all aspects of it in order to create a testable prototype. Through determining these details, they should develop a detailed design proposal, which includes all details necessary to make the prototype. Students will produce a detailed design proposal and then sequence the manufacturing process in enough detail for a third party to be able to follow to create a prototype.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **lists** some appropriate materials and components for a prototype • **lists** some appropriate manufacturing techniques for prototype production • develops a design proposal **that includes few details** • produces an **incomplete** plan **that contains some production details**.
4–6	The student: • **outlines** some appropriate materials and components for a prototype • **outlines** some appropriate manufacturing techniques for prototype production • develops a design proposal **that includes most details** • produces a plan for the manufacture of the prototype.
7–9	The student: • **justifies** the choice of appropriate materials and components for a prototype • **justifies** the choice of appropriate manufacturing techniques for prototype production • develops an **accurate and detailed** design proposal • produces a **detailed** plan for the manufacture of the prototype.

Clarifications

Justifies the choice of appropriate materials and components for a prototype
• Materials and components are identified and selected according to the requirements of the prototype. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, physical and mechanical properties, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Justifies the choice of appropriate manufacturing techniques for prototype production
• Manufacturing techniques are identified and selected according to the requirements of the prototype including joining, cutting, and so on. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, material choice, working properties of the materials, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Develops an accurate and detailed design proposal
• Develop the design to take into account the choice of materials, components and manufacturing techniques. • Use appropriate techniques and methods to finalize the details of the design (CAD, hand drawn, paper/card models) • Develop designs to sufficient detail for a third party to be able to interpret them correctly • Include details such as sizes, materials, components, assembly, production methods, and so on. The evidence for achievement against this strand should be presented in approximately three A4 pages or the equivalent.
Produces a detailed plan for the manufacture of the prototype
An appropriate plan should provide sufficient details including timings, techniques and risk assessment to allow the product to be made by a third party. Detailed plans could be presented using the following formats. • Gantt charts • Flow diagrams • Tables The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Criterion D: Testing and evaluation

Once the detailed design has been determined, a prototype can be created for testing against the marketing and design specifications. The testing should determine the success of the prototype as a solution to the initial problem and will indicate areas of weakness that the prototype has. This then allows for further iterative development. Students will evaluate the success of the solution against the specifications and then suggest how the solution can be improved.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • evaluates the success of the solution against **few** aspects of the marketing specification **with no evidence of testing** • evaluates the success of the solution against **few** aspects of the design specification **with no evidence of testing** • **lists** how the solution could be improved.
4–6	The student: • evaluates the success of the solution against **some** aspects of the marketing specification • evaluates the success of the solution against **some** aspects of the design specification • **outlines** how the solution could be improved.
7–9	The student: • evaluates the success of the solution against the marketing specification • evaluates the success of the solution against the design specification • **explains** how the solution could be improved.

Clarifications

Evaluates the success of the solution against the marketing specification
Identify strengths and weaknesses by testing the prototype(s) against the marketing specification in criterion A. • Target market • Target audience • Market analysis • User need • Competition The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Evaluates the success of the solution against the design specification
Identify strengths and weaknesses by testing the prototype(s) against the design specification in criterion A. • Cost constraints • Environmental requirements • Size constraints • Safety considerations • Performance requirements and constraints • Materials requirements • Manufacturing requirements Where possible strengths and weaknesses should be measureable. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Explains how the solution could be improved
Suggest improvements to address weaknesses identified through evaluation against marketing and design specifications. Improvements should be presented in the form of revised specifications, annotated photographs and drawings, or CAD. If the finished product does not meet either the market or the design specification, suggest modifications that are valid and feasible to bring the product up to specification. The evidence for achievement against this strand should be presented in approximately three A4 pages or the equivalent.

Internal assessment criteria—HL only

Criterion E: Commercial production

At this stage, prototypes have been developed to demonstrate proof of concept and tested successfully against the criteria detailed in the design brief and specifications. Students will modify their detailed design proposal appropriately for commercial manufacture.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **lists** appropriate materials and components for commercial production • **lists** appropriate manufacturing techniques for commercial production • **lists** design modifications to the solution required for commercial manufacture.
4–6	The student: • **outlines** appropriate materials and components for commercial production • **outlines** appropriate manufacturing techniques for commercial production • **outlines** design modifications to the solution required for commercial manufacture.
7–9	The student: • **justifies** the choice of materials and components appropriate for commercial production • **justifies** the choice of manufacturing techniques appropriate for commercial production • **explains** design modifications to the solution required for commercial manufacture.

Clarifications

Justifies the choice of materials and components appropriate for commercial production
Prototypes need to be modified in order to make them suitable for commercial production with materials and components chosen, which are compatible with the manufacturing process and design specification. • Materials and components are identified and selected according to the requirements of making the product commercially viable. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, physical and mechanical properties, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Justifies the choice of manufacturing techniques appropriate for commercial production
Manufacturing techniques should be appropriate to be effective at the chosen scale of production. • Manufacturing techniques are identified and selected according to the requirements of making the product commercially viable. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, material choice, working properties of the materials, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Explains design modifications to the solution required for commercial manufacture
The detailed design should be modified in order to be compatible with the manufacturing techniques for commercial production and the design specification. Improvements should be presented in the form of revised specifications, annotated drawings/ photographs, or CAD. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Criterion F: Marketing strategies

An invention becomes an innovation by diffusing into the marketplace. In order to increase the potential for an invention to become an innovation, marketing strategies need to be explored and implemented. Students will consider the implications of diffusing a product into the marketplace by determining the cost-effectiveness of their solution, determining the appropriate target sales price and exploring appropriate promotional strategies.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **states** a target sales price • **lists** some promotional strategies for the solution.
4–6	The student: • **identifies** a target sales price • **identifies** appropriate promotional strategies for the solution.
7–9	The student: • **justifies** an appropriate target sales price • **discusses** appropriate promotional strategies for the solution.

Clarifications

Justifies an appropriate target sales price
Evidence is required to justify the target sales price based on competing or similar products market need and break-even point. Compare the cost of existing products against the cost of making a prototype and adjust costs to suit proposed scale of manufacture. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Discusses appropriate promotional strategies for the solution
Appropriate promotional strategies should be discussed in relation to the suggested initial production run and the nature of the target market. These could include: • advertising • sales promotion • personal selling • internet marketing • sponsorship. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Rationale for practical work

Although the requirements for IA are centred on the design cycle and do not require students to create their proposed solution themselves, the different types of practical and modelling work (10 hours at SL and 26 hours at HL) that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of much design work
- developing an appreciation of designers' use of secondary data from databases
- developing an appreciation of designers' use of modelling
- developing an appreciation of the benefits and limitations of design methodology.

Therefore, there is good justification for teachers to conduct further practical activities/investigations beyond that required for the IA scheme.

Practical scheme of work

The practical scheme of work (4/PSOWDT) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. Students at SL and HL in the same subject may carry out some of the same practical activities/investigations.

Syllabus coverage

The range of practical work carried out should reflect the breadth and depth of the subject syllabus at each level, but it is not necessary to carry out a practical activity/investigation for every syllabus topic. However, all students must participate in the group 4 project and meet the requirements of the IA.

Planning your practical scheme of work

Teachers are free to formulate their own practical schemes of work by choosing practical activities/investigations according to the requirements outlined. Their choices should be based on:

- subjects and levels taught
- the needs of their students
- available resources
- teaching styles

Each scheme must include some complex practical activities/investigations that make greater conceptual demands on students. A scheme made up entirely of simple practical activities/investigations, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the OCC to share ideas about possible practical activities by joining in the discussion forums and adding resources in the subject home pages.

Creating a prototype

Students are not required to manufacture their own prototype; however, they do require a prototype of their design in order to evaluate and test it when addressing criterion D.

Students are encouraged to manufacture their own prototype; however, this can be outsourced. The prototype must be of sufficient quality so that it can be tested against the design and marketing specifications. Students may require more than one prototype to test fully.

Teacher-directed activities (formative tasks)

Time has been allocated in the course for teacher-directed tasks: 10 hours at SL and 26 hours at HL. This time can be used by teachers to direct students:

- to practise and develop appropriate design and practical skills
- to complete a mini-project that can be formatively assessed against the assessment criteria
- to ensure that a prototype is manufactured (by themselves or outsourced) for evaluation as part of the IA.

Flexibility

The practical programme is flexible enough to allow a wide variety of practical activities/investigations to be carried out. These could include:

- data-gathering exercises such as questionnaires, user trials and surveys
- using databases for secondary data

- data-analysis exercises
- developing and using different types of modelling techniques and models
- computer simulations and CAD
- focused workshop/laboratory-based practical activities or projects extending over several weeks.

Practical work documentation

Details of the practical scheme of work are recorded on *Form 4/PSOWDT* provided in the *Handbook of procedures for the Diploma Programme*.

Time allocation for practical work

The recommended teaching times for all Diploma Programme courses are 150 hours at SL and 240 hours at HL. Students at SL are required to spend 60 hours, and students at HL 96 hours, on practical activities (excluding time spent writing up work). These times include 10 hours for the group 4 project and 40 hours (SL) and 60 hours (HL) for the IA. The remaining time is allocated to teacher-directed activities.

The group 4 project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students from the different group 4 subjects analyse a common topic or problem. The exercise should be a collaborative experience where the emphasis is on the processes involved in, rather than the products of, such an activity.

In most cases students in a school would be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics—that is, there may be several group 4 projects in the same school.

Students studying environmental systems and societies are not required to undertake the group 4 project.

Summary of the group 4 project

The group 4 project is a collaborative activity where students from different group 4 subjects work together on a scientific or technological topic, allowing for concepts and perceptions from across the disciplines to be shared in line with aim 10—that is, to "develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge". The project can be practically or theoretically based. Collaboration between schools in different regions is encouraged.

The group 4 project allows students to appreciate the environmental, social and ethical implications of science and technology. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The choice of scientific or technological topic is open but the project should clearly address group 4 aims 7, 8 and 10 of the biology, chemistry and physics subject guides.

Ideally, the project should involve students collaborating with those from other group 4 subjects at all stages. To this end, it is not necessary for the topic chosen to have clearly identifiable separate subject components. However, for logistical reasons, some schools may prefer a separate subject "action" phase (see the following "Project stages" section).

Project stages

The 10 hours allocated to the group 4 project, which are part of the teaching time set aside for developing the practical scheme of work, can be divided into three stages: planning, action and evaluation.

Planning

This stage is crucial to the whole exercise and should last about two hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all group 4 students meeting to "brainstorm" and discuss the central topic, sharing ideas and information.

- The topic can be chosen by the students themselves or selected by the teachers.
- Where large numbers of students are involved, it may be advisable to have more than one mixed subject group.

After selecting a topic or issue, the activities to be carried out must be clearly defined before moving from the planning stage to the action and evaluation stages.

A possible strategy is that students define specific tasks for themselves, either individually or as members of groups, and investigate various aspects of the chosen topic. At this stage, if the project is to be experimentally based, apparatus should be specified so that there is no delay in carrying out the action stage. Contact with other schools, if a joint venture has been agreed, is an important consideration at this time.

Action

This stage should last around six hours and may be carried out over one or two weeks in normal scheduled class time. Alternatively, a whole day could be set aside if, for example, the project involves fieldwork.

- Students should investigate the topic in mixed-subject groups or single-subject groups.
- There should be collaboration during the action stage; findings of investigations should be shared with other students within the mixed/single-subject group. During this stage, in any practically based activity, it is important to pay attention to safety, ethical and environmental considerations.

Note: Students studying two group 4 subjects are not required to do two separate action phases.

Evaluation

The emphasis during this stage, for which two hours are probably necessary, is on students sharing their findings, both successes and failures, with other students. How this is achieved can be decided by the teachers, the students or jointly.

- One solution is to devote a morning, afternoon or evening to a symposium where all the students, as individuals or as groups, give brief presentations.
- Alternatively, the presentation could be more informal and take the form of a science fair where students circulate around displays summarizing the activities of each group.

The symposium or science fair could also be attended by parents, members of the school board and the press. This would be especially pertinent if some issue of local importance has been researched. Some of the findings might influence the way the school interacts with its environment or local community.

Addressing aims 7 and 8

Aim 7: "develop and apply 21st century communication skills in the study of science."

Aim 7 may be partly addressed at the planning stage by using electronic communication within and between schools. It may be that technology (for example, data logging, spreadsheets, databases and so on) will be used in the action phase and certainly in the presentation/evaluation stage (for example, use of digital images, presentation software, websites, digital video and so on).

Aim 8: "become critically aware, as global citizens, of the ethical implications of using science and technology."

Addressing the international dimension

There are also possibilities in the choice of topic to illustrate the international nature of the scientific endeavour and the increasing cooperation required to tackle global issues involving science and technology. An alternative way to bring an international dimension to the project is to collaborate with a school in another region.

Types of project

While addressing aims 7, 8 and 10 the project must be based on science or its applications. The project may have a hands-on practical action phase or one involving purely theoretical aspects. It could be undertaken in a wide range of ways:

- designing and carrying out a laboratory investigation or fieldwork
- carrying out a comparative study (experimental or otherwise) in collaboration with another school
- collating, manipulating and analysing data from other sources, such as scientific journals, environmental organizations, science and technology industries and government reports
- designing and using a model or simulation
- contributing to a long-term project organized by the school.

Logistical strategies

The logistical organization of the group 4 project is often a challenge to schools. The following models illustrate possible ways in which the project may be implemented.

Models A, B and C apply within a single school, and model D relates to a project involving collaboration between schools.

Model A: mixed-subject groups and one topic

Schools may adopt mixed-subject groups and choose one common topic. The number of groups will depend on the number of students.

Model B: mixed-subject groups adopting more than one topic

Schools with large numbers of students may choose to do more than one topic.

Model C: single-subject groups

For logistical reasons some schools may opt for single-subject groups, with one or more topics in the action phase. This model is less desirable as it does not show the mixed subject collaboration in which many scientists are involved.

Model D: collaboration with another school

The collaborative model is open to any school. To this end, the IB provides an electronic collaboration board on the OCC where schools can post their project ideas and invite collaboration from other schools. This could range from merely sharing evaluations for a common topic to a full-scale collaborative venture at all stages.

For schools with few Diploma Programme (course) students it is possible to work with non-Diploma Programme or non-group 4 students, or undertake the project once every two years. However, these schools are encouraged to collaborate with another school. This strategy is also recommended for individual students who may not have participated in the project, for example, through illness or because they have transferred to a new school where the project has already taken place.

Timing

The 10 hours that the IB recommends be allocated to the project may be spread over a number of weeks. The distribution of these hours needs to be taken into account when selecting the optimum time to carry out the project. However, it is possible for a group to dedicate a period of time exclusively to project work if all/most other schoolwork is suspended.

Year 1

In the first year, students' experience and skills may be limited and it would be inadvisable to start the project too soon in the course. However, doing the project in the final part of the first year may have the advantage of reducing pressure on students later on. This strategy provides time for solving unexpected problems.

Year 1–Year 2

The planning stage could start, the topic could be decided upon, and provisional discussion in individual subjects could take place at the end of the first year. Students could then use the vacation time to think about how they are going to tackle the project and would be ready to start work early in the second year.

Year 2

Delaying the start of the project until some point in the second year, particularly if left too late, increases pressure on students in many ways: the schedule for finishing the work is much tighter than for the other options; the illness of any student or unexpected problems will present extra difficulties. Nevertheless, this choice does mean students know one another and their teachers by this time, have probably become accustomed to working in a team and will be more experienced in the relevant fields than in the first year.

Combined SL and HL

Where circumstances dictate that the project is only carried out every two years, HL beginners and more experienced SL students can be combined.

Selecting a topic

Students may choose the topic or propose possible topics and the teacher then decides which one is the most viable based on resources, staff availability and so on. Alternatively, the teacher selects the topic or proposes several topics from which students make a choice.

Student selection

Students are likely to display more enthusiasm and feel a greater sense of ownership for a topic that they have chosen themselves. A possible strategy for student selection of a topic, which also includes part of the planning stage, is outlined here. At this point, subject teachers may provide advice on the viability of proposed topics.

- Identify possible topics by using a questionnaire or a survey of students.
- Conduct an initial "brainstorming" session of potential topics or issues.
- Discuss, briefly, two or three topics that seem interesting.
- Select one topic by consensus.
- Students make a list of potential investigations that could be carried out. All students then discuss issues such as possible overlap and collaborative investigations.

A reflective statement written by each student on their involvement in the group 4 project must be included on the coversheet for each internal assessment investigation. See the *Handbook of procedures for the Diploma Programme* for more details.

Glossary of command terms

Command terms with definitions

Students should be familiar with the following key terms and phrases used in examination questions, which are to be understood as described below. Although these terms will be used frequently in examination questions, other terms may be used to direct students to present an argument in a specific way.

These command terms indicate the depth of treatment required.

Assessment objective 1

Command term	Definition
Define	Give the precise meaning of a word, phrase, concept or physical quantity.
Draw	Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.
Find	Obtain an answer showing relevant stages in the working.
Label	Add labels to a diagram.
List	Give a sequence of brief answers with no explanation.
Measure	Obtain a value for a quantity.
Present	Offer for display, observation, examination or consideration.
State	Give a specific name, value or other brief answer without explanation or calculation.

Assessment objective 2

Command term	Definition
Annotate	Add brief notes to a diagram or graph.
Apply	Use an idea, equation, principle, theory or law in relation to a given problem or issue.
Calculate	Obtain a numerical answer showing the relevant stages in the working.

Command term	Definition
Describe	Give a detailed account.
Distinguish	Make clear the differences between two or more concepts or items.
Estimate	Obtain an approximate value.
Identify	Provide an answer from a number of possibilities.
Outline	Give a brief account or summary.

Assessment objective 3

Command term	Definition
Analyse	Break down in order to bring out the essential elements or structure.
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of the similarities between two (or more) items or situations, referring to both (all) of them throughout.
Compare and contrast	Give an account of similarities and differences between two (or more) items or situations, referring to both (all) of them throughout.
Construct	Display information in a diagrammatic or logical form.
Deduce	Reach a conclusion from the information given.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
Derive	Manipulate a mathematical relationship to give a new equation or relationship.
Design	Produce a plan, simulation or model.
Determine	Obtain the only possible answer.
Discuss	Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.
Evaluate	Make an appraisal by weighing up the strengths and limitations.
Explain	Give a detailed account including reasons or causes.
Justify	Give valid reasons or evidence to support an answer or conclusion.
Predict	Give an expected result.
Show	Give the steps in a calculation or derivation.
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.

Command term	Definition
Solve	Obtain the answer(s) using algebraic and/or numerical and/or graphical methods.
Suggest	Propose a solution, hypothesis or other possible answer.

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DESIGN TECHNOLOGY
HIGHER LEVEL
PAPER 1

SPECIMEN PAPER

1 hour

INSTRUCTIONS TO CANDIDATES

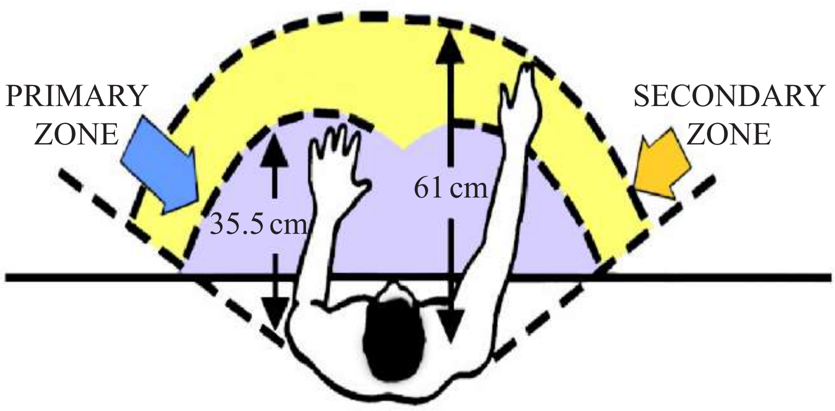
- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The maximum mark for this examination paper is *[40 marks]*.

17 pages

Blank page

1. **Figure 1** shows the workspace in front of a person. The primary zone is the area within easy reach of the hands. The secondary zone can be reached by involving arm movement.

Figure 1: Laying out a workstation in front of a person



[Source: adapted from http://ergonomicedge.wordpress.com]

Which object would be best located in the primary zone?

A. Display screen

B. Mouse

C. Stapler

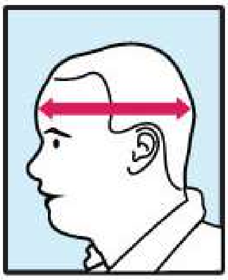
D. Heavy file

2. **Figure 2** shows a safety helmet which is produced in a range of sizes (XXS, XS, S, M, L, XL) and also has an adjustable head band to ensure that it fits properly. **Figure 3** shows the sizing of safety helmets and the measurement (in centimetres) that needs to be taken to identify the appropriate helmet size required.

Figure 2: A safety helmet with adjusable head band

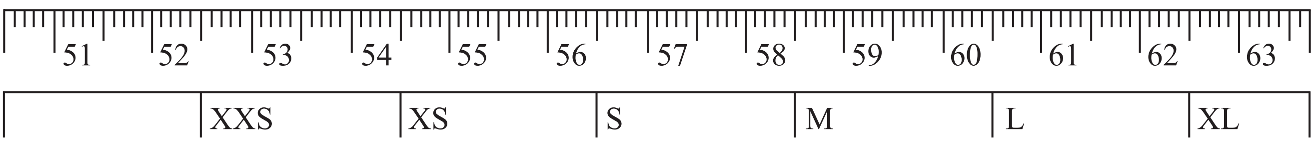
[Source: www.istockphoto.com]

Figure 3: Sizing of safety helmets



Helmet Sizing

Carefully measure around your head, above the ears. Take the measurement, in or centimetres, referring to the chart for correct, hat/helmet size. Do not guess your size, helmets must fit snugly and securely before engaging in any activity.



[Source: adapted from http://rallysport.ca]

Which helmet size would be required for a person whose head circumference is 57.5 cm?

A. XXS

B. XS

C. S

D. M

3. Which scale has units of equal size and would be suitable for use as a temperature scale?

A. Nominal

B. Ordinal

C. Interval

D. Ratio

4. What is a disadvantage for a government commissioning a nuclear energy plant?

A. High set-up costs

B. High running costs

C. High carbon emissions

D. Continuity of supply

5. Which phrase best reflects the philosophy of the circular economy?

A. Cradle to cradle

B. Cradle to grave

C. Made to be made again

D. Take, make, dispose

6. Which phrase reflects the life cycle analysis of a product?

A. Cradle to cradle

B. Cradle to grave

C. Cradle to gate

D. Cradle to site

7. At which stage of the product life cycle would user attitudes and behaviours be likely to have greater impact than those of the designer or the manufacturer?

A. Production

B. Distribution, including packaging

C. Utilization

D. Disposal

8. What aspect of eco-design does design for repair and maintenance optimize?

A. Production

B. Initial lifespan

C. Impact during use

D. End of life options

9. What would **not** necessarily be reduced by a manufacturer adopting a dematerialization strategy?

A. Depletion of natural resources

B. Waste to landfill

C. Energy consumption

D. Product efficiency

10. Which combination of intangible and tangible is reflected by a conceptual model?

	Intangible	**Tangible**
A.	No	No
B.	No	Yes
C.	Yes	No
D.	Yes	Yes

11. What is the advantage of using freehand drawings in the design process?

A. They are quick to produce and would be used for design development.

B. They can be used as working drawings for design realization.

C. They show details and dimensions and can be used for production.

D. They show the sequence of assembly of a product.

12. The Jack system provides a library of digital humans (**Figure 4**). Jack was developed to facilitate the development of the design of the NASA space shuttle. Jack is now used in a range of military applications for example, simulating maintenance and other tasks.

Figure 4: A digital human library

[Source: www.plm.automation.siemens.com]

What are the benefits of a digital human library in the simulation of maintenance tasks?

I. Dangerous tasks can be modelled virtually.

II. Humans of different sizes and weights can be used.

III. Human considerations relating to maintenance tasks can be considered early in the design process.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

13. **Figure 5** shows a lens made of photochromic material which has been partially exposed to sunlight. Photochromic lenses contain silver halides that react to ultraviolet light to darken the lens. The silver halides can be dispersed throughout the lens or can be produced as a single layer by dipping the lens in a bath of silver halide.

Figure 5: Photochromic lens partially exposed to sunlight

[Source: http://upload.wikimedia.org]

What is a disadvantage of distributing silver halides throughout lenses of variable thickness?

A. They are more expensive.

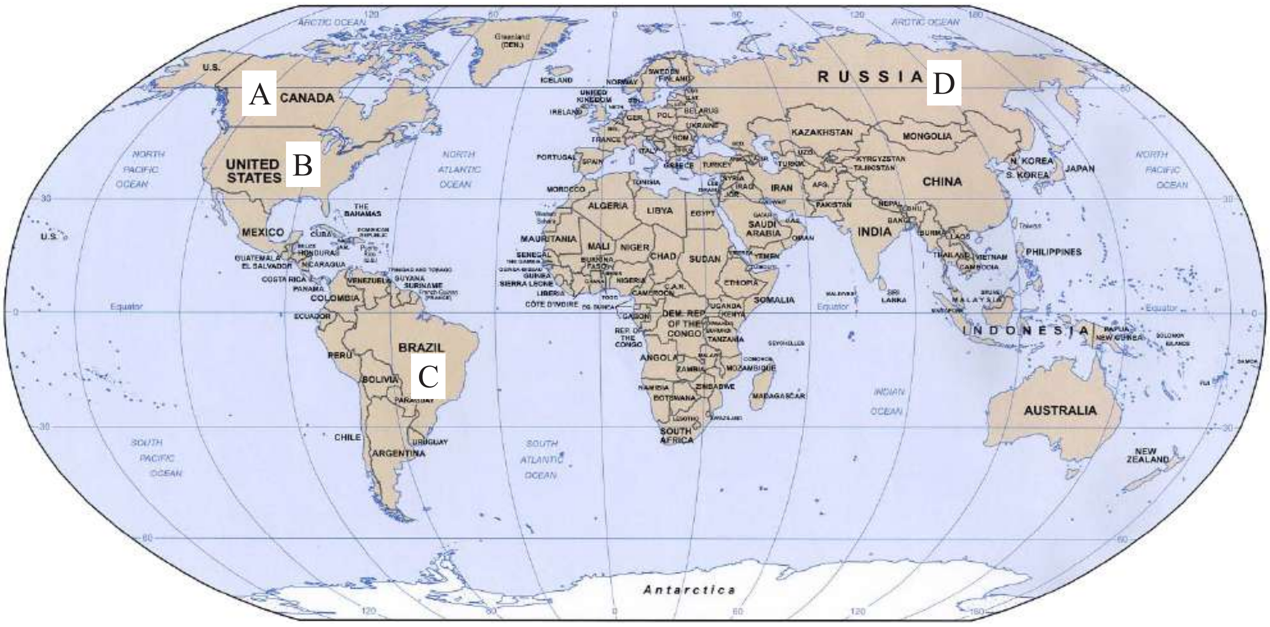
B. The lenses will darken evenly.

C. The thicker parts of the lens will darken more than the thinner parts.

D. The frame will snap back into shape if they are bent out of shape in use.

14. **Figure 6** shows a map of the world.

Figure 6: A map of the world



[Source: adapted from www.lib.utexas.edu]

In which region of the world does high demand for hardwood timber result in the depletion of ancient forests with major implications for global warming?

15. What is **not** true of assembly line production?

A. Less skilled labour is required.

B. It is suited to batch production.

C. It results in more uniform products.

D. It achieves greater efficiency.

16. Which scale of production is used for craft-produced bread?

A. One off

B. Batch

C. Mass customization

D. Mass production

17. Which intellectual property (IP) symbol is equivalent to a brand?

A. Patent

B. ©

C. ®

D. SM

18. Which of Rogers' characteristics of diffusion of innovation relates to the perception that the innovation is more satisfactory than items that already exist in the same class of products?

A. Relative advantage

B. Compatibility

C. Observability

D. Complexity

19. Which innovation stakeholder is likely to make the greatest contribution to putting an innovation into the marketplace and making it a success?

A. Designer

B. Product champion

C. Lone inventor

D. Entrepreneur

20. The publishers Phaidon have identified a collection of 999 design classics. Design classic 063 in the Phaidon collection is the paperclip (**Figure 7**) that was first patented in the United States by Samuel B Fray in 1867.

Figure 7: A paperclip

[Source: www.guardian.co.uk]

Which of Phaidon's definitions of classic design best fit the paperclip?

I. Objects that are innovative in their use of materials and unite technological advances with beautiful design.

II. Objects characterized by simplicity, balance and purity of form.

III. Objects that are perfect in their design and have remained unchanged since their creation.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

21. What is true of patents?

I. They are used to protect intellectual property.

II. They have a limited lifespan.

III. They are valid globally.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

22. What is likely to change that provides a major challenge for the designers of products for the global marketplace?

I. Task

II. User

III. Environment

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

23. What is a fictional character used in user research to represent non-users of a potential product?

A. Persona

B. Secondary persona

C. Anti-persona

D. Scenario

24. Which aspect of the four pleasure framework reflects the sensual pleasure from the sound of a well-engineered car door closing?

A. Socio-pleasure

B. Physio-pleasure

C. Psycho-pleasure

D. Ideo-pleasure

25. What is true of the United Nations Environment Programme (UNEP) International Resource Panel's definition of decoupling?

I. Economic growth and environmental impact are disconnected

II. More resources are used per unit of economic output

III. Reduced environmental impact per unit of resource

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

26. Which group of people might break laws to express their views on the environment?

A. Eco-warriors

B. Eco-champions

C. Eco-fans

D. Eco-phobes

27. Which of Datschefski's principles relates to the use of renewable energy by a sustainable product?

A. Cyclic

B. Solar

C. Safe

D. Super-efficient

28. Which term relates to the uninterrupted availability of energy sources at an affordable price?

A. Energy security

B. Peak oil

C. Renewable energy

D. Global dimming

29. What is true of product families?

I. They are a group of products based on a common platform.

II. They can facilitate the introduction of products with new features to the marketplace.

III. They can reduce production and marketing costs.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

30. Which aspect of a design specification relates to the pioneering nature of a design?

A. Patentability

B. Technical novelty

C. Environmental sustainability

D. Social sustainability

31. Which price setting strategy takes account of critical price points in consumers' minds?

A. Cost-plus pricing

B. Competitor-based pricing

C. Product line pricing

D. Psychological pricing

32. What is a major disadvantage of just in time (JIT) production?

A. Reduced storage requirements

B. Reduced inventory costs

C. Increased risk reliance on suppliers

D. Increased flexibility in responding to fluctuations in demand

33. What is a major focus of lean production?

A. Reducing waste

B. Reducing cost

C. Reducing time

D. Reducing labour

34. Which scale of production is consistent with computer-integrated manufacturing?

A. Craft

B. Mechanization

C. Batch

D. Automation

35. When do quality assurance and quality control take place relative to product manufacture?

	Quality assurance	**Quality control**
A.	Before	Before
B.	Before	After
C.	After	Before
D.	After	After

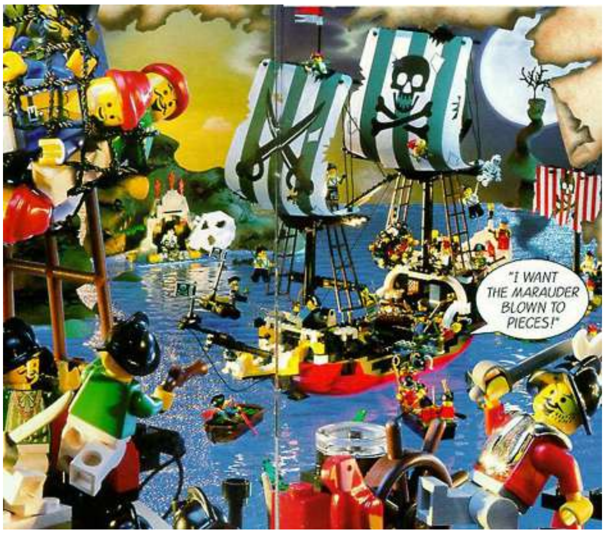
Questions 36 – 40 relate to the following case study. Please read the case study carefully and answer the questions.

Lego® is an extremely popular children's construction toy and a design classic based on interlocking bricks (**Figure 8**). Lego pieces are made of acrylonitrile butadiene styrene (ABS) and produced by injection moulding to precise sizes. Lego offers a wide range of products based on themes, for example, space, robots and pirates (**Figure 9**). New Lego products take around twelve months to develop in three stages: first, identifying market trends through designers going to toyshops and interviewing children; second, designing and developing the new product using 3D modelling software to generate CAD drawings from initial design sketches and third, prototyping using stereolithography. Prototypes are evaluated by the design team and in focus groups with parents and children. Designs are modified in line with the feedback obtained.

Figure 8: Lego® bricks

[Source:http://en.wikipedia.org]

Figure 9: Lego® set based on a pirates theme



[Source: http://images.wikia.com]

36. Which combination of toughness and plastic type characterizes the ABS plastic used for the manufacture of Lego bricks?

	Toughness	Plastic type
A.	Low	Thermoplastic
B.	Low	Thermoset
C.	High	Thermoplastic
D.	High	Thermoset

37. Which advantage of injection moulding contributes to the precision manufacturing of Lego bricks?

A. High production rates

B. Close tolerances on small intricate parts

C. Very little post-production work is required

D. Waste material can be recycled

38. What is **not** true of stereolithography for the production of the prototypes of the new Lego design?

A. It is an additive process.

B. It involves a ultraviolet light-sensitive resin.

C. It is a cheap process.

D. It is good for producing items with smooth surfaces and fine detail.

39. What is likely to be a higher priority for the target audience (children) for Lego products than for the target market (their parents)?

A. Fun

B. Health and safety

C. Cost

D. Educational value

40. Which market research strategies would require prototypes of the new Lego design?

I. User trial
II. User research
III. Expert appraisal

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

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MARKSCHEME

SPECIMEN PAPER

DESIGN TECHNOLOGY

Higher Level

Paper 1

2 pages

1.	B	16.	B	31.	B	46.	–
2.	C	17.	C	32.	C	47.	–
3.	C	18.	A	33.	A	48.	–
4.	C	19.	D	34.	D	49.	–
5.	C	20.	C	35.	B	50.	–
6.	B	21.	A	36.	C	51.	–
7.	D	22.	C	37.	B	52.	–
8.	D	23.	C	38.	C	53.	–
9.	D	24.	B	39.	A	54.	–
10.	C	25.	B	40.	B	55.	–
11.	A	26.	A	41.	–	56.	–
12.	D	27.	B	42.	–	57.	–
13.	C	28.	A	43.	–	58.	–
14.	C	29.	D	44.	–	59.	–
15.	A	30.	A	45.	–	60.	–

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DESIGN TECHNOLOGY
STANDARD LEVEL
PAPER 1

SPECIMEN PAPER

45 minutes

INSTRUCTIONS TO CANDIDATES

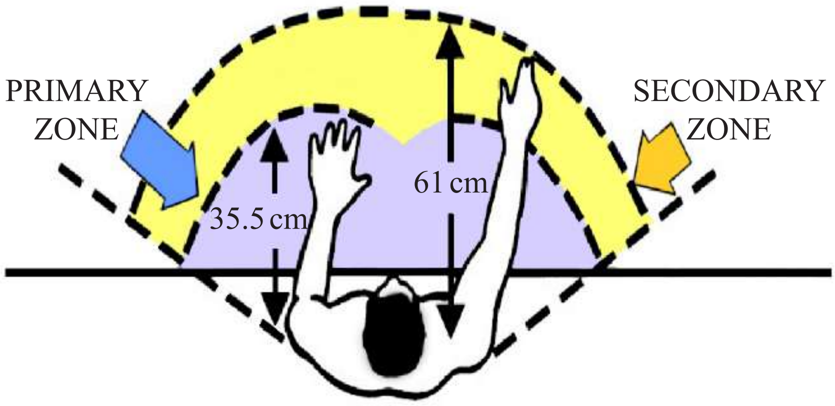
- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The maximum mark for this examination paper is *[30 marks]*.

15 pages

Blank page

1. **Figure 1** shows the workspace in front of a person. The primary zone is the area within easy reach of the hands. The secondary zone can be reached by involving arm movement.

Figure 1: Laying out a workstation in front of a person



[Source: adapted from http://ergonomicedge.wordpress.com]

Which object would be best located in the primary zone?

A. Display screen

B. Mouse

C. Stapler

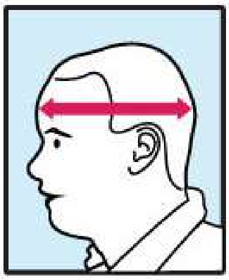
D. Heavy file

2. **Figure 2** shows a safety helmet which is produced in a range of sizes (XXS, XS, S, M, L, XL) and also has an adjustable head band to ensure that it fits properly. **Figure 3** shows the sizing of safety helmets and the measurement (in centimetres) that needs to be taken to identify the appropriate helmet size required.

Figure 2: A safety helmet with adjusable head band

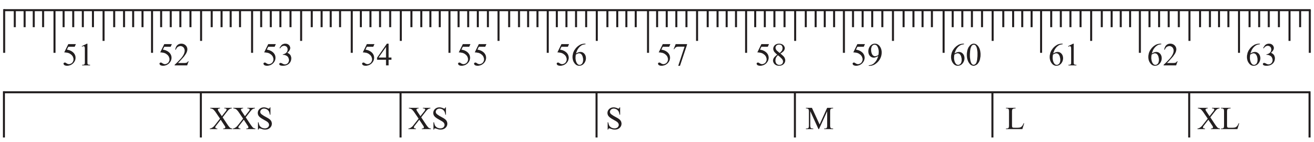
[Source: www.istockphoto.com]

Figure 3: Sizing of safety helmets



Helmet Sizing

Carefully measure around your head, above the ears. Take the measurement, in centimetres, referring to the chart for correct, hat/helmet size. Do not guess your size, helmets must fit snugly and securely before engaging in any activity.



[Source: adapted from http://rallysport.ca]

Which helmet size would be required for a person whose head circumference is 57.5 cm?

A. XXS

B. XS

C. S

D. M

3. Which part of the human information processing system converts a nerve impulse from the brain into an action?

A. Sensory processes

B. Central processes

C. Motor processes

D. Output

4. Which consideration in the design of an open-plan office would have an impact on an employee's thermal comfort by influencing the rate of evaporation of sweat from the skin?

A. Air temperature

B. Radiant heat from heat sources, for example, electrical equipment

C. Air velocity

D. Humidity

5. Which phrase best reflects the philosophy of the circular economy?

A. Cradle to cradle

B. Cradle to grave

C. Made to be made again

D. Take, make, dispose

6. Which phrase reflects the life cycle analysis of a product?

A. Cradle to cradle

B. Cradle to grave

C. Cradle to gate

D. Cradle to site

7. Which combination of incremental and radical reflects the addition of an end-of-pipe technology to a manufacturing system?

	Incremental	**Radical**
A.	No	No
B.	No	Yes
C.	Yes	No
D.	Yes	Yes

8. A design objective for a greener washing powder would be to?

A. Increase corporate profit

B. Reduce environmental impact

C. Increase the product’s effectiveness

D. Reduce the amount of product used

9. What aspect of eco-design does design for repair and maintenance optimize?

A. Production

B. Initial lifespan

C. Impact during use

D. End of life options

10. Which would be facilitated by the use of modular design as part of a company's eco-design strategy?

I. Ease of maintenance
II. Design for reuse
III. Design for recycling

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Which green design strategy is related to the use of materials from obsolete products to create new products?

A. Reuse

B. Recycle

C. Repair

D. Recondition

12. Which combination of intangible and tangible is reflected by a conceptual model?

	Intangible	Tangible
A.	No	No
B.	No	Yes
C.	Yes	No
D.	Yes	Yes

13. What is the advantage of using freehand drawings in the design process?

A. They are quick to produce and can be used for design development.

B. They can be used as working drawings for design realization.

C. They show details and dimensions and can be used for production.

D. They show the sequence of assembly of a product.

14. Which scale would be used for a prototype?

A. 1:1

B. 1:10

C. 1:100

D. 1:1000

15. Which rapid prototyping technique involves the use of a laser?

I. Selective laser sintering (SLS)
II. Stereolithography
III. Laminated object manufacture (LOM)

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. A horseshoe (**Figure 4**) is made by beating heated metal into shape and then cooling it very quickly by dipping into cold water – a process called quenching.

Figure 4: A horseshoe

[Source: http://en.wikipedia.org]

What is the effect of beating and quenching the heated metal during the manufacture of the horseshoe?

I. Hardening of the metal

II. Smaller grain size

III. Larger grain size

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

17. Which parts of a stress-strain curve correspond to the elastic limit?

A. Yield point

B. Fracture point

C. Ultimate tensile strength

D. Plastic region

18. Which generation of robots are able to recognize speech?

A. First

B. Second

C. Third

D. Fourth

19. Which combination of volume of production and individuality of product is achieved by automation?

	Volume of production	**Individuality of product**
A.	Low	Low
B.	Low	High
C.	High	Low
D.	High	High

20. **Figure 5** shows a lens made of photochromic material which has been partially exposed to sunlight. Photochromic lenses contain silver halides that react to ultraviolet light to darken the lens. The silver halides can be dispersed throughout the lens or can be produced as a single layer by dipping the lens in a bath of silver halide.

Figure 5: Photochromic lens partially exposed to sunlight

[Source: http://upload.wikimedia.org]

What is a disadvantage of distributing silver halides throughout lenses of variable thickness?

A. They are more expensive.

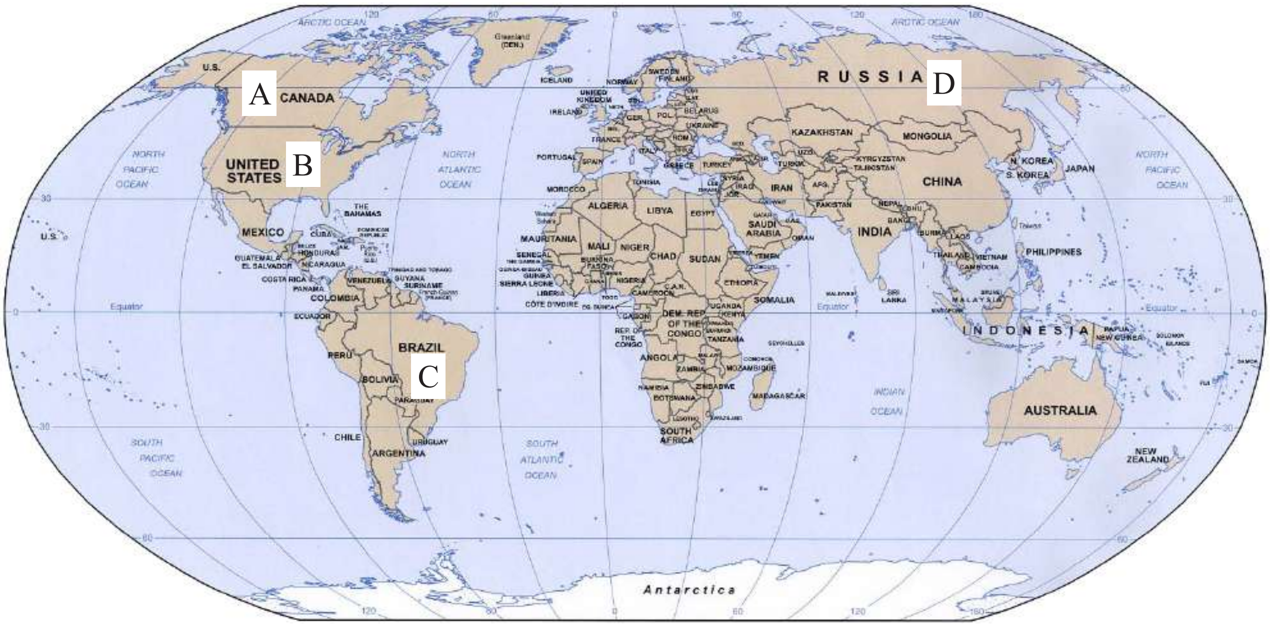
B. The lenses will darken evenly.

C. The thicker parts of the lens will darken more than the thinner parts.

D. The frame will snap back into shape if they are bent out of shape in use.

21. **Figure 6** shows a map of the world.

Figure 6: A map of the world



[Source: adapted from www.lib.utexas.edu]

In which region of the world does high demand for hardwood timber result in the depletion of ancient forests with major implications for global warming?

22. What is **not** true of assembly line production?

A. Less skilled labour is required.

B. It is suited to batch production.

C. It results in more uniform products.

D. It achieves greater efficiency.

23. Which scale of production is used for craft-produced bread?

A. One off

B. Batch

C. Mass customization

D. Mass production

24. Which of Rogers' characteristics of diffusion of innovation relates to the perception that the innovation is more satisfactory than items that already exist in the same class of products?

A. Relative advantage

B. Compatibility

C. Observability

D. Complexity

25. At which stage of the product life cycle would sales of a product be slow and profitability low?

A. Launch

B. Growth

C. Maturity

D. Decline

26. What is **not** an example of a disruptive innovation?

A. Digital photography

B. Light emitting diodes (LEDs)

C. Wikipedia

D. Solar panels

Questions 27–30 relate to the following case study. Please read the case study carefully and answer the questions.

The publishers Phaidon have identified a collection of 999 design classics. Design classic 063 in the Phaidon collection is the paperclip (**Figure 7**) that was first patented in the United States by Samuel B Fray in 1867. Paperclips are made by bending steel (an alloy of iron and carbon) wire.

Figure 7: A paperclip

[Source: www.guardian.co.uk]

27. Which of Phaidon's definitions of classic design best fit the paperclip?

I. Objects that are innovative in their use of materials and unite technological advances with beautiful design.

II. Objects characterized by simplicity, balance and purity of form.

III. Objects that are perfect in their design and have remained unchanged since their creation.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

28. Which mechanical property is important in producing wire for the manufacture of the wire for the paperclips?

A. Malleability

B. Conductivity

C. Density

D. Ductility

29. What is true of patents?

I. They are used to protect intellectual property.

II. They have a limited lifespan.

III. They are valid globally.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

30. What is a defined as a mixture that contains at least one metal?

A. Metallic ore

B. Alloy

C. Smart material

D. Grain

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MARKSCHEME

SPECIMEN PAPER

DESIGN TECHNOLOGY

Standard Level

Paper 1

2 pages

1.	B	16.	A	31.	–	46.	–
2.	C	17.	A	32.	–	47.	–
3.	C	18.	C	33.	–	48.	–
4.	D	19.	C	34.	–	49.	–
5.	C	20.	C	35.	–	50.	–
6.	B	21.	C	36.	–	51.	–
7.	C	22.	A	37.	–	52.	–
8.	B	23.	B	38.	–	53.	–
9.	D	24.	A	39.	–	54.	–
10.	A	25.	D	40.	–	55.	–
11.	B	26.	D	41.	–	56.	–
12.	C	27.	C	42.	–	57.	–
13.	A	28.	D	43.	–	58.	–
14.	A	29.	A	44.	–	59.	–
15.	D	30.	B	45.	–	60.	–

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DESIGN TECHNOLOGY
HIGHER LEVEL AND STANDARD LEVEL
PAPER 2

SPECIMEN PAPER

1 hour 30 minutes

Candidate session number

Examination code

					–				

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the boxes provided.
- A calculator is permitted for this paper.
- The maximum mark for this examination paper is *[50 marks]*.

SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

1. Current legislation requires universities to provide access for wheelchair users to halls of residence and the rooms where students live. Design teams work to maximize the number of wheelchair accessible rooms and ensure full access to all features of the rooms for wheelchair users.

Figure 1: Plan view of a university room layout
all dimensions are in mm

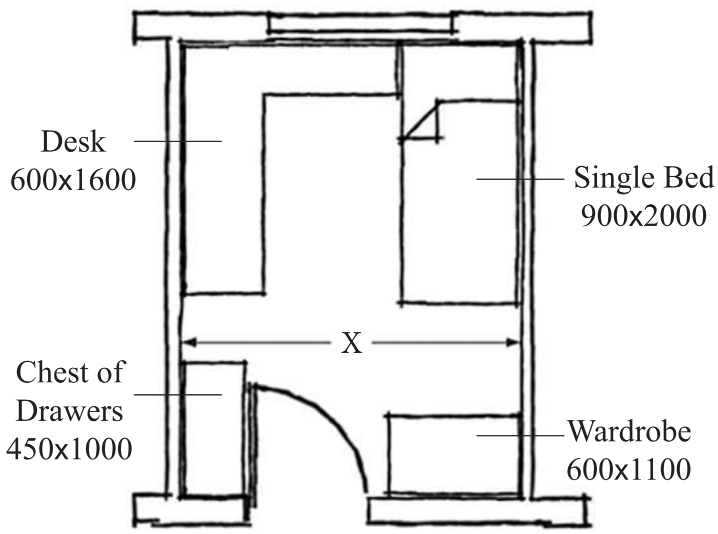


Figure 2: Existing university wardrobe

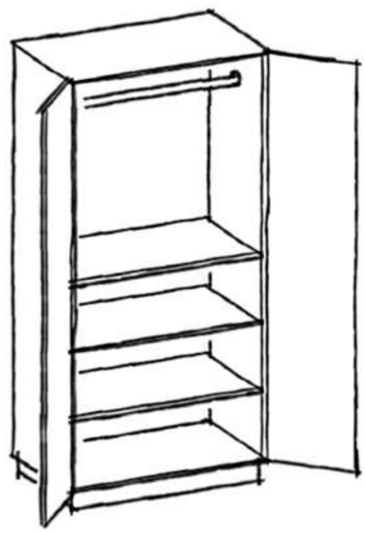
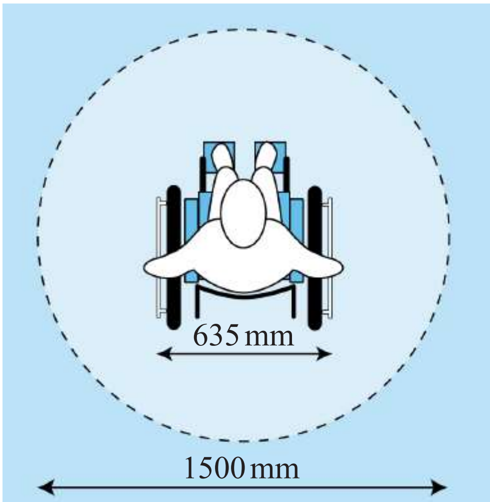


Figure 3: Basic manual wheelchair with arms and foot rests

[Source: www.etac.com]

Figure 4: Basic manual wheelchair turning circle



[Source: adapted from www.portsmouth.gov.uk]

(This question continues on the following page)

(Question 1 continued)

(a) (i) State **one** reason why door openings for manual wheelchair users must be more than 65 cm. *[1]*

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(ii) Calculate the **minimum** dimension “X” required for the room in **Figure 1** for wheelchair access. *[2]*

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(b) (i) Outline **one** feature of the wheelchair in **Figure 3** that may prevent users from pulling up to/rolling under a standard desk. *[2]*

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(ii) Describe **one** physiological factor related to the design of the seat for wheelchair users. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(c) (i) Outline the relevance of collecting primary data to inform the redesign of the university's rooms for wheelchair accessibility. *[2]*

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(ii) Explain **one** feature designers need to modify for the wardrobe in **Figure 2** to be accessible for wheelchair users. *[3]*

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(This question continues on page 6)

Please **do not** write on this page.

Answers written on this page
will not be marked.

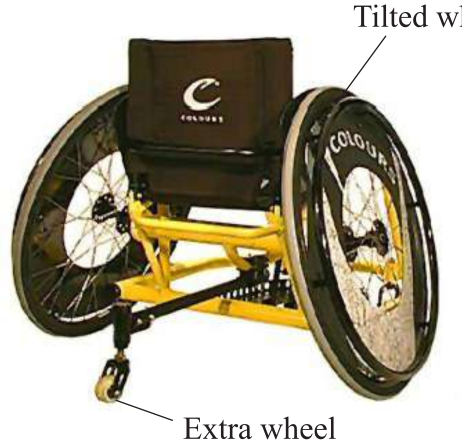
(Question 1 continued from page 4)

Many wheelchairs are designed for specialist purposes. The wheelchairs shown in **Figure 5** are designed for basketball and rugby players. **Figure 6** shows the side and rear views of a Hammer sports wheelchair.

Figure 5: Basketball wheelchairs

[Source: www.wheelchairbasketball.ca]

Figure 6: Side and rear views of a Hammer sports wheelchair



[Source: www.1800wheelchair.ca]

(This question continues on the following page)

(Question 1 continued)

(d) (i) Outline **one** way a larger wheel diameter assists an athlete in the sports wheelchair shown in **Figure 5**. *[2]*

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(ii) Outline **one** benefit of having the front of the wheelchair seat higher up than the back of the seat on the sports wheelchair in **Figure 6**. *[2]*

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(e) (i) Outline **one** benefit of the additional rear wheels shown in **Figures 5** and **6**. *[2]*

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(ii) Outline **one** benefit of tilting the large wheels of sports wheelchairs. *[2]*

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2. **Figure 7** below shows a printer-scanner-fax machine.

Figure 7: A printer-scanner-fax machine

[Source: www.brother.fr]

(a) Describe how the printer-scanner-fax machine shown in **Figure 7** meets the criteria for converging technology. *[2]*

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(b) Outline **one** advantage of converging technologies for the environment. *[2]*

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3. Explain how the use of "design for the environment" software assists designers in choosing materials. *[3]*

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4. Discuss why the use of thermoplastic renders a product green but not sustainable. *[3]*

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SECTION B

*Answer **one** question. Write your answers in the boxes provided.*

5. The screen, shown in **Figure 8**, is a flexible screen developed for smart phones. This flexibility is achieved by replacing the layers of glass in conventional screens with a new plastic material. The screen has been developed so electronic products that use it can bend without breaking.

Figure 8: Flexible smart phone screen

[Source: www.behance.net]

(a) Outline **one** advantage of electronic products that use this flexible screen other than flexibility. *[2]*

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(This question continues on the following page)

(Question 5 continued)

(b) Explain **one** advantage of flexible screens for outdoor advertising. *[3]*

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(c) Explain **two** ways smart phones can utilize a flexible screen. *[6]*

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(This question continues on the following page)

(Question 5 continued)

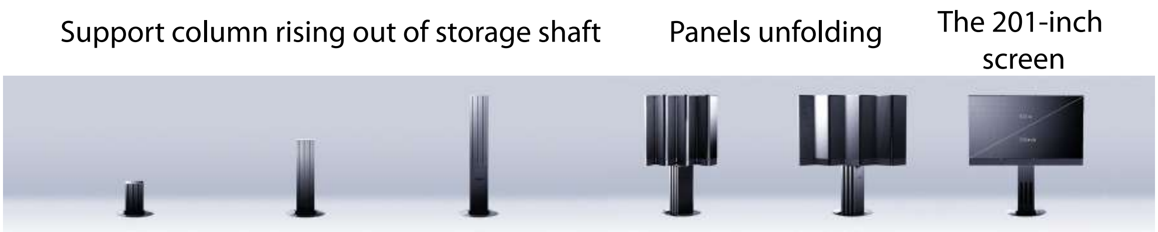
(d) Explain how relative advantage, trialability and observability impact on the rate of consumer adoption of flexible screen based smart phones. *[9]*

6. The C SEED 201, shown in **Figure 9**, is an outdoor TV (television) by Porsche Design Studio. When the TV is not being watched, it is stored underground in a waterproof shaft. The touch of a button on the TV's remote control opens the lid of the storage shaft. A pillar-shaped support column then rises to as high as 4.6 metres. Once the stand reaches its set height, seven large screen panels unfold to form the 201-inch TV, in less than a minute, as shown in **Figure 10**.

Figure 9: The C SEED 201 outdoor TV

[Source: www.justluxe.com]

Figure 10: Stages of assembling the C SEED 201 outdoor TV



[Source: www.cseed.tv]

(a) Outline why the C SEED 201 outdoor TV is a combination of both radical and incremental design. *[2]*

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(Question 6 continued)

(b) Explain the innovation strategy behind the C SEED 201 name. *[3]*

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(c) Explain **two** ways virtual prototypes assist the design development of this TV. *[6]*

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(Question 6 continued)

(d) Explain how the safety, convenience and technology specification may have influenced the design of this TV. *[9]*

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7. Cotton towel, paper towels, warm air hand dryers and jet-air hand dryers are used in different public places.

Figure 11: Cotton towel dryer

[Source: www.libertyhygiene.com]

Figure 12: Paper towel dispenser

[Source: http://trade.indiamart.com]

Figure 13: Push button warm air hand dryer

[Source: www.xpblocker.com]

Figure 14: Automatic warm air hand dryer

[Source: www.bradleycorp.com]

Figure 15: Automatic jet air hand dryer

[Source: http://blog.coverall.com]

(a) Outline **one** possible driver for the invention of hand dryers to replace paper towel dispensers. *[2]*

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(This question continues on the following page)

(Question 7 continued)

(b) Discuss the relationship between form and function to the design of the opening for hands in the jet air hand dryer shown in **Figure 15**. *[3]*

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(c) Discuss **two** issues why the cotton towel dryer shown in **Figure 11** is not suitable for large-scale use. *[6]*

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(This question continues on the following page)

(Question 7 continued)

(d) Compare paper towels (**Figure 12**) and warm air hand dryers (**Figures 13** and **14**) in relation to convenience, sustainabilty and hygiene. *[9]*

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will not be marked.

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MARKSCHEME

SPECIMEN PAPER

DESIGN TECHNOLOGY

Higher Level and Standard Level

Paper 2

10 pages

General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) through Scoris™, by e-mail or telephone – if through Scoris™ or by e-mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader through Scoris™ or by e-mail at any time if they have any problems/queries regarding marking. For any queries regarding the use of Scoris™, please contact emarking@ibo.org.

If you have any queries on **administration** please contact:

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Cardiff Gate
Cardiff CF23 8GL
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Tel: +(44) 29 2054 7777

Fax: +(44) 29 2054 7778

E-mail: sue.blackhurst@ibo.org

1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

3. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

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7. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers. Scoris™ will only award the highest mark or marks in line with the rubric.

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Subject Details: Design Technology HL and SL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A (total ***[30 marks]***) **ONE** question in Section B ***[20 marks]***. Maximum total = ***[50 marks]***.

1. A markscheme often has more marking points than the total allows. This is intentional.

2. Each marking point has a separate line and the end is shown by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking indicate this by adding **ECF** (error carried forward) on the script.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

SECTION A

1. (a) (i) *Award* ***[1]*** *for stating one reason why the door openings for manual wheelchair users must be more than 65cm.*
enough room is needed for arms, hands of wheelchair users;
extra space if wheelchair user is carrying anything wider than the wheelchair; ***[1 max]***

(ii) *Award* ***[1]*** *for calculation and award* ***[1]*** *for a correct answer* ***[2 max]****.*
$600+1500+900; = 3000\,\text{mm}$; ***[2 max]***

(b) (i) *Award* ***[1]*** *for stating one wheelchair feature that may prevent users from pulling up to/rolling under a standard desk and* ***[1]*** *for a reason why* ***[2 max]****.*
armrests;
fixed wheelchair armrests prevent users from pulling up to/rolling under desk;

footrest;
floor to knee height is affected by the height of footrest above the floor; ***[2 max]***

(ii) *Award* ***[1]*** *for stating one physiological factor related to the design of the seat for wheelchair users and* ***[1]*** *for a brief description* ***[2 max]****.*
comfort;
seat must provide good postural support;
since wheelchair users may have to sit in the same position for long periods of time;

proper padding/cushioning;
for pressure relief/avoid sores; ***[2 max]***

(c) (i) *Award* ***[1]*** *for stating one relevance of collecting primary data to inform the redesign of the university's rooms for wheelchair accessibility and* ***[1]*** *for a brief explanation* ***[2 max]****.*
feedback regarding the relationship between a wheelchair user and the room, with its equipment/furniture, may only be obtained through primary data;
feedback is different if secondary data on individual aspects of the room or the wheelchair user are looked at individually; ***[2]***

(ii) *Award **[1]** for stating one feature designers need to modify for the wardrobe in Figure 2 to be accessible for wheelchair users and **[1]** for each of two points of explanation **[3 max]**.*
wheelchair users have a lower reach;
top rail is inaccessible for them;
designers need to add a mechanism to pull down the top rail;

a wheelchair limits clearance in front of a closet;
making it more difficult to open closet doors/remain clear of door's swing;
designers need to install bi-fold/sliding doors instead of out swinging doors;

wheelchairs limit how close users may get to the closet;
wheelchair users approach the closet parallel and twist sideways to reach within;
increasing the height and depth of the recess at the front of the closet (toe-kick space) allows them to roll up straight; ***[3 max]***

(d) (i) *Award **[1]** for stating one way a larger wheel diameter assists athletes on the sports wheelchair and **[1]** for a reason why **[2 max]**.*
less effort is required;
since fewer rotations are needed to cover the same distance;

easy to grab the wheel;
due to increased height/surface area; ***[2 max]***

(ii) *Award **[1]** for stating one benefit of having the front of the wheelchair seat higher up than the back of the seat on the sports wheelchair and **[1]** for a reason why **[2 max]**.*
greater degree of stability;
athletes are less likely to fall out of seat during games; ***[2]***

(e) (i) *Award **[1]** for stating one benefit for the additional rear wheels and **[1]** for a reason why **[2 max]**.*
anti-tip/balance/stability;
prevents wheelchair from falling backward; ***[2]***

(ii) *Award **[1]** for stating one benefit of tilting the large wheels of sports wheelchairs and **[1]** for a reason why **[2 max]**.*
wider base;
provides extra side to side stability/makes it less likely for wheelchair to tip over sideways;

hands and fingers are protected;
from contact with other wheelchairs during group sports;

quicker turning;
as athletes have better access to a wheel's hand rim; ***[2 max]***

2. (a) *Award **[1]** for each of two points in a description of how the printer-scanner-fax machine meets the criteria for converging technology **[2 max]**.*
one machine;
combines three functions; ***[2]***

(b) *Award **[1]** for stating one advantage of converging technologies for the environment and **[1]** for a brief explanation **[2 max]**.*
fewer products/ less need to purchase three separate products;
less materials, energy and resources are used up/more resources are conserved;
less waste/pollution manufacture; ***[2 max]***

3. *Award **[1]** for stating how the use of "design for the environment" software assists designers in choosing materials and **[1]** for each of two distinct correct points in an explanation **[3 max]**.*
designers use "design for the environment" software to identify the effects of their material choices on the environment;
and compare it with similar/alternative materials;
in order to impact as little as possible on the environment; ***[3]***

4. *Award **[1]** for stating why the use of thermoplastic renders a product green but not sustainable and **[1]** for each of two distinct correct points in an explanation **[3 max]**.*
plastic may be recycled/reused thus it is green;
creating plastic raw material causes environmental problems so it is not sustainable;
plastic is not a renewable resource thus it is not sustainable; ***[3]***

SECTION B

5. (a) *Award **[1]** for stating one advantage of electronic products that use a flexible screen and **[1]** for a brief explanation **[2 max]**.*
lower density;
without the glass screens are more lightweight;

plastic layers are thinner than glass;
electronic products become slimmer; ***[2 max]***

(b) *Award **[1]** for stating one advantage of flexible screens for outdoor advertising and **[1]** for each of two distinct correct points in an explanation **[3 max]**.*
advertising space no longer needs to be flat;
screens can go round uneven surfaces *eg* poles, columns;
increasing opportunities/advertising space; ***[3]***

(c) *Award **[1]** for each of three distinct correct points in a discussion of two ways in which smart phones can utilize a flexible screen. **[3 max per way, 6 max]**.*
curved displays;
screens can curve on the sides/back of a rectangular smart phone; or take a totally different shape by wrapping around arms and wrists *eg* wrist phones;

compact sizes;
screens can be bent/rolled;
to reduce the size of smart phones when not in use; ***[6]***

(d) *Award **[1]** for each of three distinct correct points in an explanation of how relative advantage, trialability and observability impact on the rate of consumer adoption of flexible screen based smart phones **[3 max per aspect, 9 max]**.*
relative advantage:
adoption rates are affected by the degree to which consumers perceive the attributes of flexible screen based smart phone as better than the phones they supersede;
the main attribute of such phones is flexibility;
the more consumers who view this as a positive attribute the higher the rate of adoption;

trialability:
A flexible screen based smart phone that is trialable prior to purchase represents less uncertainty/risk to consumers;
gives them more confidence to adopt the new phone;
limited base trials of such smart phones may be provided via marketing/promotion campaigns;

observability:
The more the advantages/positive effects of flexible screen based smart phones are visible to consumers the more quickly they will spread;
smart phones are highly visible products;
and may be observed in a number of different situations *eg* when socializing, through advertising and innovative marketing campaigns; ***[9]***

6. (a) *Award **[1]** for each point in an outline of why the C SEED 201 TV is a combination of both radical and incremental design **[2 max]**.*
the way it is stored and opened is a radical approach;
but it is an incremental development of existing TV screens; ***[2]***

(b) *Award **[1]** for stating the innovation strategy behind the C SEED 201 name and **[1]** for each of two distinct correct points in an explanation **[3 max]**.*
analogy;
eyes see images on TV thus the letter "C";
the TV rises from its shaft and unfolds like a seed grows into a tree/plant; ***[3]***

(c) *Award **[1]** for stating each of two ways virtual prototypes assist the design development of this TV and **[1]** for each distinct point in an explanation of each way **[3 max per way, 6 max]**.*
virtual prototypes may be used for FEA testing;
FEA shows how the support column, panels and screen behave under different stresses;
to modify critical high stress areas *eg* when the column is rising, panels are unfolding and when the screen is fully open;

virtual prototypes provide a realistic simulation;
to communicate how the TV rises and unfolds clearly;
and allow for different types of feedback/evaluation; ***[6]***

(d) *Award **[1]** for each of three distinct points in an explanation of how safety, convenience and technology specification may have influenced the design of this TV **[max 3 per aspect, 9 max]**.*
safety:
pillar should not rise if there is something on top of the storage shaft;
screen should automatically fold in adverse weather conditions *eg* strong winds and high temperature;
remote control should be equipped with a safety lock for activating the storage shaft;
column and screen structure must be stable;

technology:
high screen resolution to ensure perfect pictures even on bright days;
distortion free sound in different weather conditions;
fold/unfold screen mechanism;
raising and lowering the column;
waterproof storage shaft;

convenience:
TV is stored out of sight until needed;
short time to raise, unfold/fold and lower the TV;
screen should rotate sideways;
column height should adjust to raise and lower the screen as needed; ***[9 max]***

7. (a) *Award **[1]** for stating one possible driver for the invention of hand dryers to replace paper towel dispensers and **[1]** for a brief explanation.*
sustainability;
desire to save resources/save trees/reduce waste;

constructive discontent;
dissatisfaction with using paper to dry hands; ***[2 max]***

(b) *Award **[1]** for each of three distinct points in a discussion of the relationship between form and function to the design of the opening for hands in the jet air hand dryer **[3 max]**.*
the opening is tilted outward and rounded for easy entry of hands;
the length of opening allows both hands to fit in side by side;
the width of opening is enough for a wide variety of hand thicknesses;
the channel in which hands are placed in is deep enough to take the 95^{th} percentile of hand length; ***[3 max]***

(c) *Award **[1]** for stating each of two issues why the cotton towel hand dryer is not suitable for large-scale use and **[1]** for each of two distinct points of discussion per issue **[3 max per issue, 6 max]**.*
size of towel roll;
limits the available amount of clean towels;
allowing less users to dry their hands because of hygiene issues;

laundry;
cotton towels must be periodically changed and washed;
leading to higher consumption of valuable resources *eg* water and energy; ***[6]***

(d) *Award **[1]** for each of three distinct points in a comparison of paper towels and warm air hand dryers in relation to convenience, sustainability and hygiene **[3 max per aspect, 9 max]**.*
convenience:
paper towels may be used to dry hands outside restrooms;
paper towels are not noisy;
paper towels are more convenient when drying other body parts *eg* face;
hands may not be dry enough within the automatic time limit of warm air hand dryers;

sustainability :
warm air hand dryers save trees;
paper towels create waste unless recycled;
paper towels require packaging, waste/trash bins and bin liners;
paper towels can be made from recycled materials;
warm air hand dryers consume energy;

hygiene:
some warm air hand dryers require users to push a button which may expose them to germs;
air blowing on hands may blow away bacteria on others in the restroom;
used paper towels pile up in waste/trash bins inside restrooms; ***[9 max]***

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DESIGN TECHNOLOGY
HIGHER LEVEL
PAPER 3

Candidate session number

SPECIMEN PAPER

Examination code

1 hour 30 minutes

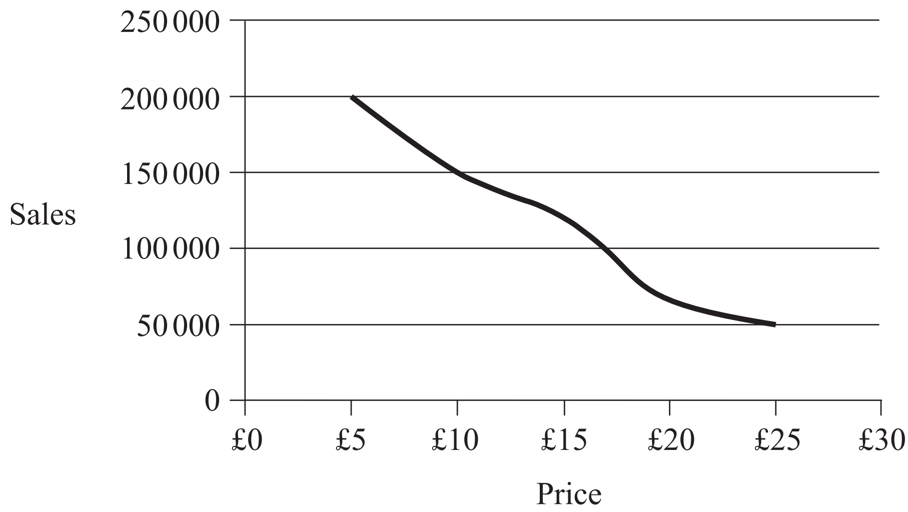
INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions.
- Write your answers in the boxes provided.
- A calculator is permitted for this paper.
- The maximum mark for this examination paper is *[40 marks]*.

SECTION A

1. A company which manufacturers a range of computer accessories is considering future strategies in product development and the management of the production process. The company has used the graph in **Figure 1** to try and decide on its pricing policy for products and Kaizen has been discussed as a possible strategy to improve production.

Figure 1: Graph of predicted sales compared to price



(a) Outline the type of pricing strategy depicted in **Figure 1**. *[2]*

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(b) Outline how the pricing strategy shown in **Figure 1** is influenced by production costs. *[2]*

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(Question 1 continued)

(c) Outline cost-plus pricing. *[2]*

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(d) Explain how the concept of Kaizen helps to improve the efficiency of the production process. *[4]*

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2. **Figure 2** shows the Panasonic NN-CT870WBPQ microwave/convection oven designed for the domestic sector. It can be used either as a microwave oven or a conventional oven/grill. **Figure 3** shows the Panasonic NE1856 microwave oven designed for commercial use in fast food outlets, cafes *etc*. **Table 1** shows some of the specifications for each oven. *[1]*

Figure 2: NN-CT870WBPQ domestic microwave oven

Figure 3: NE1856 commercial microwave oven

[Source: www.panasonic.co.uk]

Table 1: Specifications for each oven

Domestic microwave oven	Commercial microwave oven
1000 w power output for microwave	1800 w power output
Convection cooking range 100 – 250 °C	Programmable touch pads with 3 power levels
1500 w radiant grill	Stainless steel body
Auto sensor programs to calculate cooking times	Easy to clean interior with removable ceiling plate
Child lock feature	Two ovens can be stacked on top of each other safely
White painted (enamelled) body	Clear digital display

[Source: www.panasonic.co.uk]

(This question continues on the following page)

(Question 2 continued)

(a) Describe the function of a usability laboratory in assisting with the design development of the microwave oven in **Figure 2**. *[2]*

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(b) Outline how empathic design may help with the design of the microwave oven in **Figure 3**. *[2]*

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(c) Explain how the requirements of the market sectors for each of the microwave ovens shown in **Figures 2** and **3** impact on the design of each oven. *[6]*

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SECTION B: Case Study

Royal Philips Electronics is a major global manufacturer of lighting, electronics, electrical and medical equipment. Philips has included sustainability as an integral part of its corporate strategy since 2002. In its Sustainability Report (2005) the company states that sustainable development is a priority for the board of management based on the "triple bottom line" of economic, social and environmental responsibilities. The Sustainability Report states that socially and environmentally responsible behaviour contributes to sustained profitable growth which is why sustainable thinking and acting is embedded in all the daily activities of the company.

Philips is also committed to supporting social and community activities across the globe. For example, in 2012 Philips and the Dutch Football Association (KNVB) established a three year partnership built around the creation of 90 solar community light centers across the African and South American continents. The light centers are approximately 1000 m^2 and lit by highly-efficient solar-powered LED lighting. They provide an area of light for rural communities without electricity so creating opportunities for social, sporting and economic activities in the evening (**Figure 4**).

Figure 4: Philips Community Light Center

[Source: www.philips.com]

Philips adopted a systematic strategy to take into account environmental issues in 1994 starting with a green design approach which has developed into sustainable design and sustainable innovation polices. The policies encompass setting targets for its different product divisions although it is not expected that each division will meet targets at the same rate. This is in recognition that the targets are more difficult to achieve for some divisions than others and may be dependent on the products and services provided. The design teams in each division are expected to take into account the green focus areas of: weight; hazardous substances; energy consumption; recycling; disposal and packaging, with improvement to be made in at least two of these green focus areas.

As part of its sustainability vision, Philips sees the markets of the developing world as both an economic opportunity and a way to meet its social and environmental responsibilities. To do this Philips asked its employees to come up with innovative business ideas that address the needs of the poor which involve partnerships between local Philips businesses and other organizations based on innovation in products and services. An example is the SimplyHealthy@Schools project which is a global community programme established by Philips to help underprivileged school children live healthier lives. Employees of the company engage children in the "Healthy Heroes Toolkit" which shows them how they can improve their health. In 2012 Philips employees travelled to over 100 schools in 37 countries to support this project.

3. (a) Outline the influence of timescale on Philips' strategy to move from a green design approach to a sustainable design approach. *[3]*

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(b) Outline why Philips's corporate strategy for triple bottom line sustainability is a top-down approach. *[3]*

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(Question 3 continued)

(c) Explain how Philips promotes ethical consumerism. *[5]*

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(d) Discuss **three** issues which Philips is likely to have considered when incorporating sustainable design and sustainable innovation into their corporate strategy. *[9]*

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MARKSCHEME

SPECIMEN PAPER

DESIGN TECHNOLOGY

Higher Level

Paper 3

General Marking Instructions

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If you have any queries on **administration** please contact:

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1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

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Subject Details: Design Technology HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions. Maximum total = ***[40 marks]***

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2. Each marking point has a separate line and the end is shown by means of a semicolon (;).

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10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme**.**

SECTION A

1. (a) *Award **[1]** for stating the pricing strategy depicted in Figure 1 and **[1]** for a brief explanation **[2 max]**.*
demand pricing;
volume of sales based on the correlation between price and demand; ***[2]***

(b) *Award **[1]** for each correct distinct point in an outline of how the pricing strategy shown in Figure 1 is influenced by production costs **[2 max]**.*
account needs to be taken of the variation in costs of production at different levels of sales;
break-even point for each level of sales needs to be calculated in order to choose the price which will provide the greatest profit; ***[2]***

(c) *Award **[1]** for each correct distinct point in an outline of cost-plus pricing **[2 max]**.*
estimating the average cost of producing and marketing a product;
then adding a mark-up to make a profit; ***[2]***

(d) *Award **[1]** for each distinct point in an explanation of how Kaizen helps to improve the efficiency of the production process **[4 max]**.*
Kaizen focuses on continuous improvement of the production process;
it involves all employees and the supply chain;
by improving efficiency it aims to reduce waste;
so is complementary to a philosophy of lean production; ***[4]***

2. (a) *Award* ***[1]*** *for each distinct point in a description of the function of a usability laboratory in assisting with the design development of the microwave oven in Figure 2* ***[2 max]****.*
to observe/test users carrying out pre-determined tasks with the oven;
to provide data/research into how users interact with the oven which can underpin design ideas; ***[2]***

(b) *Award* ***[1]*** *for each correct distinct point in an outline of how empathic design may help with the design of the microwave oven in Figure 3* ***[2 max]****.*
the designers can be in contact/empathize with potential users of the oven;
in order to gain a better understanding of the users' thoughts/needs/values/beliefs; ***[2]***

(c) *Award* ***[1]*** *for each distinct point in a discussion of how the requirements of the market sectors for each of the microwave ovens shown in Figures 2 and 3 impact on the design of each oven* ***[3 max per market sector, 6 max]****.*
commercial oven:
durability important as it will be used many times a day/stainless steel body for durability;
it must be easy to clean as it is likely to be used by different users in one location who may be busy/rushed causing many food spills;
the oven has a large grab handle which will be easy to grip even with wet hands;
the controls are large and simple to interpret/use;
aesthetics are less important than function;

domestic oven:
aesthetics important so it looks good in the kitchen;
white colour so it fits in with other white goods in the kitchen;
small push-button controls which are delicate to use/small number of users will learn the functions;
integrated push button door control which lies flush with the surface/integrated design;
child lock feature for safety for families with small children;
multi-function use so suitable for small kitchens/people who do not cook often/ do not cook large meals; ***[6 max]***

SECTION B

3. (a) *Award **[1]** for each of three correct distinct points in an outline of the influence of timescale on Philips' strategy to move from a green design approach to a sustainable design approach **[3 max]**.*
sustainable design takes longer to implement than green design;
as it focuses on all aspects of the design cycle;
rather than just one green focus area; ***[3]***

(b) *Award **[1]** for each of three correct distinct points in an outline of why Philips's corporate strategy for triple bottom line sustainability is a top-down approach **[3 max]**.*
the corporate strategy was decided by executives/Board of Management as the way forward for the company;
targets have been imposed on each division of the company in line with this strategy;
although employees are given the opportunity to contribute to the strategy with ideas they do not have a choice to ignore it; ***[3]***

(c) *Award **[1]** for each of five correct distinct points in an explanation of how Philips promotes ethical consumerism **[5 max]**.*
Philips has a responsibility to shareholders to make a profit but strategies for innovation also focus on improving the lives of poor people in developing countries;
who do not have the income/resources to be consumers of Philips products;
Philips sustainability strategy is embedded in the design brief for all products;
so it promotes ethical consumerism across the total customer base;
even if customers do not care about sustainability issues; ***[5]***

(d) *Award **[1]** per distinct point in a discussion of three issues which Philips is likely to have considered when incorporating sustainable design and sustainable innovation into their corporate strategy **[3 max per issue, 9 max]**.*
resistance from employees;
who do not fully understand the concepts/are reluctant to embrace the concepts;
and resent the targets set for sustainability;

complexity of products;
Philips designs and manufactures a wide range/diverse range of products;
some of which are more suitable for redesign taking into account sustainability factors than others;

consumer reaction;
many consumers will not be aware/are not interested in sustainability issues;
they just want value for money in a competitive market;
Philips has to incorporate its sustainability strategy without pricing itself out of its traditional markets;

reaction of shareholders;
Philips is a global company with a diverse shareholder base;
shareholders may not share the vision of the board of management;
especially if profits suffer because of it;

changing political/economic climates;
governments/organizations can change policy/legislation relating to sustainability;
and it may be difficult for Philips to adapt its strategy to satisfy new targets/legislation;

pioneering strategy to sustainability by Phillips;
but other companies may imitate their sustainable products without having to spend much money on R&D;
meaning that they can sell similar products more cheaply;

difficulty of choosing which community projects to support;
there are so many worthy projects worldwide that Philips can only support a small percentage of them;
there is a possibility of alienating some market sectors by failing to support projects within the sector which have been presented to the company; ***[9 max]***

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: IB Design Tech **GRADE: 11/12**

Unit	Standards	Unit Concept /Essential Ideas	Assessments
1: Human Factors and Ergonomics 2: Resource Management and Sustainable Production 3: Modelling 4: Raw Materials to Final Production 5: Innovation and Design 6: Classic Design	Syllabus and cross-curricular links are provided in the IB Design Tech Guide available on the International Baccalaureate Online Curriculum Center and attached as a pdf document.	Key Concepts Concepts and Essential Ideas are outlined in detail throughout the IB Design Tech Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Content Specific Vocabulary Key Terms are outlined in detail throughout the IB Design Tech Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document.	Formative quizzes and summative tests are generated using the IB Design Tech Question bank (a database of prior exam questions). Specimen Papers with example questions are available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. Performance tasks are outlined in the IB Design Tech Guide available on the International Baccalaureate Online Curriculum Center and are attached as a pdf document. These include applications and skills, international mindedness and theory of knowledge connections, as well as utilizations and aims of concepts.

TEACHER'S NAME: Timothy Elmer **6/17**

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 1 – Design Process

Desired Results *(stage 1)*

ESTABLISHED GOALS

It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools

Transfer

TRANSFER: Students will be able to independently use their learning to …

- T1 – Apply the engineering design process to design a system, component, or process to meet desired needs within realistic constraints.
- T2 – Understand the role and impact of engineering and engineering solutions within a global, economic, environmental, and societal context.

Meaning

UNDERSTANDINGS: Students will understand that …

- U1 – An engineering design process involves a characteristic set of practices and steps used to develop innovative solutions to problems.
- U2 – Brainstorming may take many forms and is used to generate a large number of innovative, creative ideas in a short time.
- U3 – Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms.
- U4 – Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.
- U5 – Engineering consists of a variety of specialist sub-fields, with each contributing in different ways to the design and development of solutions to different types of problems.

ESSENTIAL QUESTIONS: Students will keep considering …

- Q1 -- When solving an engineering problem, how can we be reasonably sure that we have created the BEST solution possible? What is the evidence?
- Q2 – What is the most effective way to generate potential solutions to a problem? How many alternate solutions are necessary to ensure a good final solution?
- Q3 – What engineering accomplishment of the 20th century has had the greatest impact on society? Justify your answer.
- Q4 – What will be the biggest impact that engineering will have on society and your life in the 21st century? Justify your answer.
- Q5 – Engineering tends to be a male-dominated profession. Why is that?

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	Acquisition	
necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	*KNOWLEDGE: Students will …* • K1 – Identify the steps in an engineering design process and describe the activities involved in each step of the process. U1 • K2 – Explain the concept of proportion and how it relates to freehand sketching. U4 • K3 – Identify and describe a variety of brainstorming techniques and rules for brainstorming. U2 • K4 – Differentiate between invention and innovation. U1 • K5 – Identify and differentiate between the work of an engineer and the work of a scientist. U5 • K6 – Identify and differentiate between mechanical, electrical, civil, and chemical engineering fields. U5	*SKILLS: Students will …* • S1 – Generate and document multiple ideas or solution paths to a problem through brainstorming. U1, U2, U4 • S2 – Describe the design process used in the solution of a particular problem and reflect on all steps of the design process. U1 • S3 – Utilize an engineering notebook to clearly and accurately document the design process according to accepted standards and protocols to prove the origin and chronology of a design. U1, U3, U4 • S4 – Create sketches or diagrams as representations of objects, ideas, events, or systems. U4 • S5 – Explain the contributions of engineers from different engineering fields in the design and development of a product, system, or technology. U5 • S6 – Review and evaluate the written work of peers and make recommendations for improvement. U3

Format guided by: Wiggins, G. & McTighe, J. (2011). The understanding by design guide to creating high quality units. Alexandria, VA: ASCD

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Activity 1.1 Instant Challenge: Cable Car	• Conclusion Questions #1-3	
Small Group/Class Discussion: Essential Question – How might we create the best possible solution to a problem?	• Teacher considers student responses and preconceptions in order to inform effective teaching	
Activity 1.2 Instant Challenge Aerodynamic Distance	• Conclusion Questions #1-3	
Activity 1.3 Concept Sketching	• Realistic and proportional representations in sketches	• Realistic and proportional representations in sketches • Conclusion questions #1-4
Activity 1.4 Product Improvement	• Quantity and variety in brainstorming ideas.	• Realistic and proportional representations in sketches. • Conclusion questions #1-3
Activity 1.5 The Deep Dive	• Appropriate classification of the tasks involved in a design process. • Conclusion Question #1,4,5,6	• Conclusion questions #2,3
Activity 1.6 Discover Engineering	• Understanding of appropriate descriptions of the roles and responsibilities of	• Conclusion questions # 1, 3

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
A1.1 Instant Challenge: Cable Car	S1
A 1.2 Instant Challenge: Aerodynamic Distance	S1
A 1.3 Concept Sketching	K1, K2, S4
A 1.4 Product Improvement	S1, S4
A 1.5 Deep Dive	K1, S2
A 1.6 Discover Engineering	K3, K5, K6, S5
A 1.6b Engineering and Related STEM Careers (Optional)	S5, STEM Career Exploration

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	civil, chemical, mechanical and electrical engineers. • Conclusion question # 2, 4			
Activity 1.7 **What Is It?**	• Thorough peer review of essay using rubric. • Incorporation of suggested changes by author	• A 1.7 Rubric	A 1.7 What Is It?	K4, K6, S10, S5, S6
Activity 1.8 **Instant Challenge: Paper Bridge**	• Conclusion question #3 [Teamwork]	• Effective use and documentation of the design process (Engineering Notebook) • Design meets constraints and criteria of problem • Conclusion questions # 1, 2	A 1.8 Instant Challenge: Paper Bridge	K1, S1, S2, S3, S4
Activity 1.9 **Design Innovation**	• Appropriate classification of chosen design as invention or innovation • Appropriate research and documentation • Conclusion questions #2 - 4	• Conclusion question #1	A 1.9 Design Innovation	K6, S5
Unit Assessment Items	• All items	• All items		
Summative – EoC		• All items		

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 2 – Technical Sketching and Drawing

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Use the accepted practices and techniques of engineering graphics and technical drawings to clearly convey information and ideas.
• T2 – Poficiently apply spatial skills to conceptualize and understand objects in 3D space and visualize and understand mental rotation of objects and how they appear in different positions.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.
• U2 – Hand sketching of multiple representations to fully and accurately detail simple objects or parts of objects is a technique used to convey visual and technical information about an object.
• U3 – Two- and three-dimensional objects share visual relationships which allow interpretation of one perspective from the other.
• U4 – The style of the engineering graphics and the type of drawing views used to detail an object vary depending upon the intended use of the graphic.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – How is technical drawing similar to and different from artistic drawing?
• Q2 – What can cause a technical drawing to be misinterpreted or to be inadequate when conveying the intent of a design to someone unfamiliar with the original problem or solution?
• Q3 – In what ways can technical drawings help or hinder the communication of problem solution in a global community?
• Q4 – Strong spatial-visualization skills have been linked to success in engineering. Why are spatial-visualization skills so important to engineering success?</td></tr>
</table>

	Acquisition	
modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	*KNOWLEDGE: Students will …* • K1 – Identify line types (including construction lines, object lines, hidden lines, and center lines) used on a technical drawing per ANSI Line Conventions and Lettering Y14.2M-2008 and explain the purpose of each line. U1 • K2 – Identify and define technical drawing representations including isometric, orthographic projection, oblique, and perspective views. U1, U4 • K3 – Identify the proper use of each technical drawing representation including isometric, orthographic projection, oblique, and perspective views. U1, U4	*SKILLS: Students will …* • S1 – Apply tonal shading to enhance the appearance of a pictorial sketch and create a more realistic appearance of a sketched object. U1, U4 • S2 – Hand sketch isometric views of a simple object or part at a given scale using the actual object, a detailed verbal description of the object, a pictorial view of the object, or a set of orthographic projections. U1, U2, U4 • S3 – Hand sketch 1-point and 2-point perspective pictorial views of a simple object or part given the object, a detailed verbal description of the object, a pictorial view of the object, and/or a set of orthographic projections. U1, U2, U4 • S4 –Select flat patterns (nets) that fold into geometric solid forms. U3 • S5 – Hand sketch orthographic projections at a given scale and in the correct orientation to fully detail an object or part using the actual object, a detailed verbal description of the object, or a pictorial and isometric view of the object. U1, U2, U3, U4 • S6 – Determine the minimum number and types of views necessary to fully detail a part. U1, U4 • S7 – Choose and justify the choice for the best orthographic projection of an object to use as a front view on technical drawings. U1, U4

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
A2.1 Isometric Sketching	• Peer/teacher assessment of Sketching tasks 4 – 8	• Essential Question 1 • Additional sketches from #6 and $8 • Conclusion Questions
Small Group/Class Discussion: Essential Question 1	Teacher considers student responses and preconceptions in order to inform effective teaching	
A2.2 Perspective Sketching	• Peer/teacher assessment of sketching tasks 3 – 5 • Conclusion Questions 1 - 2	• Additional sketches of puzzle pieces or from #5 • Conclusion Question 3
Class Discussion: Essential Question 2	Teacher considers student responses and preconceptions in order to inform effective teaching	
A2.3 Glass Box	• Conclusion Questions	
A2.4 Multi-view Sketching	• Peer/teacher assessment of sketching tasks 3 – 5 • Conclusion Questions 1 - 2	• Conclusion Question 3 – 5 • Additional sketches from Extending Your Learning
A2.5 Sketching Practice	• Conclusion Questions	• All tasks and and conclusion questions
Small Group/Class Discussion: Essential Questions 3 and 4	Teacher considers student responses and preconceptions in order to inform effective teaching	
Interim/Common Assessment	All items	All items
Summative – EoC		All items

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
A2.1 Isometric Sketching	K1, K2, K3, S1, S2
A2.2 Perspective Sketching	K1, K2, K3, S1, S3
A2.3 Glass Box	K1, K2, K3, S4, S5
A2.4 Multi-view Sketching	K1, K2, K3, S5, S6, S7
A2.5 Sketching Practice	K1, K2, K3, S1, S2, S3, S4, S5, S7

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Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 3 – Measurement and Statistics

Desired Results *(stage 1)*

ESTABLISHED GOALS
It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools

Transfer

TRANSFER: *Students will be able to independently use their learning to …*

- T1 – Analyze and interpret data in order to make valid and reliable claims or determine optimal design solutions.
- T2 – Apply mathematics and computational thinking (specifically ratios, rates, percentages, and unit conversions) to solve problems involving quantities and units (including derived or compound units).

Meaning

UNDERSTANDINGS: *Students will understand that …*

- U1 – Error is unavoidable when measuring physical properties, and a measurement is characterized by the precision and accuracy of the measurement.
- U2 – Units and quantitative reasoning can guide mathematical manipulation and the solution of problems involving quantities.
- U3 – Dimensions are included on technical drawings according to accepted practice and an established set of standards so as to convey size and location information about detailed parts and their features.
- U4 – Statistical analysis of uni-variate data facilitates understanding and interpretation of numerical data and can be used to inform, justify, and validate a design or process.
- U5 – Spreadsheet programs can be used to store, manipulate, represent, and analyze data efficiently.

ESSENTIAL QUESTIONS*: Students will keep considering …*

- Q1 – Can statistics be interpreted to justify conflicting viewpoints? Can this affect how we use statistics to inform, justify and validate a problem solution?
- Q2 -- Why is error unavoidable when making a measurement?
- Q3 – When recording measurement data, why is the use of significant figures important?
- Q4 – What strategy would you use to teach another student how to use units and quantitative reasoning to solve a problem involving quantities? (For example, a problem like A3.2 number 4 or number 5.)
- Q5 – What would happen if engineers did not follow accepted dimensioning standards and guidelines but, instead, used their own individual dimensioning methods?
- Q6 – When measuring the length of a part, would an inaccurate (but precise) measuring instrument be more or less likely to indicate the actual measurement than an

<table>
<tr>
<td rowspan="3">necessary for engineering practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.</td>
<td></td>
<td>imprecise (but accurate) measuring instrument? Justify your answer.</td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>KNOWLEDGE: Students will …

• K1 – Identify general rules for dimensioning on technical drawings used in standard engineering practice. U3
• K2 – Distinguish between sample statistics and population statistics and know appropriate applications of each. U4
• K3 – Distinguish between precision and accuracy of measurement. U1</td>
<td>SKILLS: Students will …

• S1 – Measure linear distances (including length, inside diameter, and hole depth) with accuracy using a scale, ruler, or dial caliper and report the measurement using an appropriate level of precision. U1
• S2 – Use units to guide the solution to multi-step problems through dimensional analysis and choose and interpret units consistently in formulas. U2
• S3 – Convert quantities between units in the SI and the US Customary measurement systems. U2
• S4 – Convert between different units within the same measurement system including the SI and US Customary measurement systems. U2
• S5 – Dimension orthographic projections of simple objects or parts according to a set of dimensioning standards and accepted practices. U3
• S6 – Identify and correct errors and omissions in the dimensions applied in a technical drawing based on accepted practice and a set of dimensioning rules. U5
• S7 – Calculate statistics related to central tendency including mean, median, and mode. U4
• S8 – Calculate statistics related to variation of data including (sample and population) standard deviation and range. U4
• S9 – Represent data with plots on the real number line (e.g., dot plots, histograms, and box plots). U4
• S10 – Use statistics to quantify information, support design decisions, and justify problem solutions. U4
• S11 – Use a spreadsheet program to store and manipulate raw data. U5
• S12 – Use a spreadsheet program to perform calculations</td>
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		using formulas. U5 • S13 – Use a spreadsheet program to create and display a histogram to represent a set of data.U5 • S14 – Use function tools within a spreadsheet program to calculate statistics for a set of data including mean, median, mode, range, and standard deviation. U5 • S15 – Use the Empirical Rule to interpret data and identify ranges of data that include 68 percent of the data, 95 percent of the data, and 99.7 percent of the data given the appropriate descriptive statistics. U4 • S16 – Choose a level of precision and accuracy appropriate to limitations on measurement when reporting quantities.U1 • S17 – Evaluate and compare the accuracy and precision of different measuring devices. U1, U4

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Activity 3.1a Linear Measurement with Metric Units	• Tasks #9 and #10 • Conclusion Questions	• Tasks similar to #9 and #10
Activity 3.1b Linear Measurement with US Customary Units	• Peer/teacher assessment of Tasks #10 and #11 • Conclusion Questions	• Tasks similar to #10 and #11
Journal Entry: Essential Question 2	Teacher considers student responses and preconceptions in order to inform effective teaching	
Activity 3.2 Unit Conversion	• Conclusion Questions	
Activity 3.2h Unit Conversion Homework		• Peer/teacher evaluation of all tasks
Journal Entry: Essential Question 4	Teacher considers student responses and preconceptions in order to inform effective teaching	
Activity 3.3 Making Linear Measurements	• Optional task from #5 • Conclusion Questions	• Optional task from #5
Activity 3.3 Making Linear Measurements ALTERNATE	• Conclusion Questions	• Optional task from A3.3 #5
Activity 3.4 Linear Dimensions	• Peer/teacher assessment of task #10 • Conclusion Questions	• Extend Your Learning #11 – 13. • Follow instructions for #8 with another puzzle cube piece
Class Discussion: Essential Question 5	Teacher considers student responses and preconceptions in order to inform effective teaching	

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
Activity 3.1a Linear Measurement with Metric Units	S1
Activity 3.1b Linear Measurement with US Customary Units	S1
Activity 3.2 Unit Conversion	S2, S3, S4
Activity 3.2h Unit Conversion Homework	S2, S3, S4
Activity 3.3 Making Linear Measurements	S1
Activity 3.3 Making Linear Measurements ALTERNATE	S1
Activity 3.4 Linear Dimensions	K1, S5, S6

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Activity 3.5 Applied Statistics	• Conclusion Questions	• Follow instructions for #2 with alternate Automoblox data
Activity 3.6 Instant Challenge: Fling Machine		• Conclusion Questions
Activity 3.7 Statistical Analysis with Excel Statistical Analysis Examples	• Peers compare results of Parts 2 and Parts 3 • Conclusion Questions	• Conclusion Question 1
Activity 3.8 Precision and Accuracy of Measurement	• Peer/teacher assessment of task #3 • Conclusion Questions	
Small Group/Class Discussion or Journal Entry: Essential Question 3 and Essential Question 6	Teacher considers student responses and preconceptions in order to inform effective teaching	
Activity 3.9 Statistics and Quality		• Peer/teacher assessment of all tasks
Small Group/Class Discussion: Essential Question 1	Teacher considers student responses and preconceptions in order to inform effective teaching	
Activity 3.10 Instant Challenge: Oil Spill (Optional)	• Conclusion Questions	
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

Activity 3.5 Applied Statistics	S7, S8, S9
Activity 3.6 Instant Challenge: Fling Machine	S7, S8, S9, S10, S14
Activity 3.7 Statistical Analysis with Excel Statistical Analysis Examples	K2, S11, S12, S13
Activity 3.8 Precision and Accuracy of Measurement	K2, K3, S1, S9, S10, S11, S12, S13, S14, S15, S16, S17
Activity 3.9 Statistics and Quality	S1, S10, S11, S12, S13, S14
Activity 3.10 Instant Challenge: Oil Spill (Optional)	S7

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 4 – Modeling Skills

Desired Results *(stage 1)*

ESTABLISHED GOALS
It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering

Transfer

TRANSFER: *Students will be able to independently use their learning to …*

- T1 – Use the engineering design process to design a system, component, or process to meet desired needs within realistic constraints.
- T2 – Create and use mathematical/computational models or simulations to represent design solutions or support explanations.
- T3 – Develop and use multiple types of models to analyze systems, components or processes and/or to solve problems.
- T4 – Use current engineering tools (ex., spreadsheet software, CADD software) in problem solving and engineering design.

Meaning

UNDERSTANDINGS: *Students will understand that …*

- U1 – Technical professionals use a variety of models to represent systems, components, processes and other designs including graphical, computer, physical, and mathematical models.
- U2 – Computer aided drafting and design (CAD) software packages facilitate the creation of virtual 3D computer models of parts and assemblies.
- U3 – Physical models are created to represent and evaluate possible solutions using prototyping technique(s) chosen based on the presentation and/or testing requirements of a potential solution.
- U4 – Technical professionals clearly and accurayely

ESSENTIAL QUESTIONS: *Students will keep considering …*

- EQ1 – How should one decide what information and/or artifacts to include in a portfolio? Should a portfolio always include documentation on the complete design process?
- EQ2 – Did you use every possible type of model during the design and construction of your puzzle cube? Describe each model that you used?
- EQ3 – How reliable is a mathematical model?

<table>
<tr>
<td rowspan="3">practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.</td>
<td>document and report their work using technical writing practice in multiple forms.
• U5 – An equation is a statement of equality between two quantities that can be used to describe real phenomenon and solve problems.
• U6 – Solving mathematical equations and inequalities involves a logical process of reasoning and can be accomplished using a variety of strategies and technological tools.
• U7 – A function describes a special relationship between two sets of data and can be used to represent a real world relationship and to solve problems.</td>
<td></td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>KNOWLEDGE: Students will …

• K1 – Explain the term “function” and identify the set of inputs for the function as the domain and the set of outputs from the function as the range. U7
• K2 – Be familiar with the terminiology related to and the use of a 3D solid modeling program in the creation of solid models and technical drawings. U2
• K3 – Differentiate between additive and subtractive 3d solid modeling methods. U2</td>
<td>SKILLS: Students will …

• S1 – Develop and/or use graphical, computer, physical and mathematical models as appropriate to represent or solve problems.
• S2 – Fabricate a simple object from technical drawings that may include an isometric view and orthographic projections. U1, U5
• S3 – Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings using appropriate geometric and dimensional constraints. U1, U2
• S4 – Generate CAD multi-view technical drawings, including orthographic projections and pictorial views, as necessary, showing appropriate scale, appropriate view selection, and correct view orientation to fully describe a simple part according to standard engineering practice. U1, U2
• S5 – Construct a testable prototype of a problem solution. U1, U3</td>
</tr>
</table>

		• S6 – Analyze the performance of a design during testing and judge the solution as viable or non-viable with respect to meeting the design requirements. U3 • S7 – Create a set of working drawings to detail a design project. U1, U2 • S8 – Organize and express thoughts and information in a clear and concise manner. U4 • S9 – Utilize project portfolios to present and justify design projects. U4 • S10 – Use a spreadsheet program to graph bi-variate data and determine an appropriate mathematical model using regression analysis. U1, U7 • S11 – Construct a scatter plot to display bi-variate data, investigate patterns of association, and represent the association with a mathematical model (linear equation) when appropriate. U1, U5 • S12 – Solve equations for unknown quantities by determining appropriate substitutions for variables and manipulating the equations. U6 • S13 – Use function notation to evaluate a function for inputs in its domain and interpret statements that use function notation in terms of a context. U7 • S14 – Build a function that describes a relationship between two quantities given a graph, a description of a relationship, or two input-output pairs. U1, U7 • S15 – Interpret a function to solve problems in the context of the data. U6, U7 • S16 – Interpret the slope (rate of change) and the intercept (constant term) of a linear function in the context of data. U1, U5 • S17 – Compare the efficiency of the modeling method of an object using different combinations of additive and subtractive methods. U2

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
P4.1 Puzzle Design Challenge		• P4.1 Rubric • Conclusion Questions
Class Discussion: Essential Question 1	• Teacher considers student responses and preconceptions in order to inform effective teaching	
A4.1a Puzzle Part Combinations	• Puzzle piece sketches • Conclusion Questions	
A4.1b Graphical Modeling	• Peer review of sketches per task #6	
A4.1c Mathematical Modeling	• Peers compare/correct answers to Parts 2 and 3	• Conclusion Questions
Small Group/Class Discussion: Essential Question 3	• Teacher considers student responses and preconceptions in order to inform effective teaching	
A4.1d Software Modeling Introduction (Digital STEAM)	• Conclusion Questions	
A4.1e Software Modeling Introduction (Video Download)	• Conclusion Questions	
A4.1f Software Modeling Introduction Reference	n/a	n/a
A4.1g Model Creation	• Peers compare physical properties of 3D models in Inventor and identify mistakes. • Conclusion Questions	• Student modeling of a simple solid object similar to those included in activity from a dimensioned isometric view

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
P4.1 Puzzle Design Challenge	S1, S2, S3, S4, S5, S6, S7, S8, S9
A4.1a Puzzle Part Combinations	S1
A4.1b Graphical Modeling	S1, (S2), S8
A4.1c Mathematical Modeling	K1, S1, S10, S11, S12, S13, S14, S15, S16
A4.1d Software Modeling Introduction (Digital STEAM)	K2, S1
A4.1e Software Modeling Introduction (Video Download)	K2, S1
A4.1f Software Modeling Introduction Reference	
A4.1g Model Creation	K2, K3, S1, S3, S17

Journal Entry: Essential Question 3		• Teacher assesses student responses
A4.2 Puzzle Cube Package (Optional)	• Conclusion Questions	• A4.2 Rubric
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

A4.2 Puzzle Cube Package (Optional)	(S1, S2, S5)

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 5 – Geometry of Design

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Use current engineering tools (ex., spreadsheet software, CADD software) to create models, solve problems and perform engineering design.
• T2 – Apply geometric concepts and methods to describe and model objects and solve problems.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Geometric shapes and forms are described and differentiated by their characteristic features.
• U2 – Physical properties of objects are used to describe and model objects and can be used to define design requirements, as a means to compare potential solutions to a problem, and as a tool to specify final solutions.
• U3 – Computer aided design (CAD) and drafting software packages incorporate the application of a variety of geometric and dimensional constraints and model features to accurately represent objects.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• EQ1 – What advantage(s) do Computer Aided Design (CAD) and Drafting provide over traditional paper and pencil design? What advantages does paper and pencil design provide over CAD?
• EQ2 – Which high school math topic/course, Algebra or Geometry, is more closely related to engineering? Justify your answer.
• EQ3 – How does the material chosen for a product impact the design of the product?</td></tr>
</table>

Format guided by: Wiggins, G. & McTighe, J. (2011). The understanding by design guide to creating high quality units. Alexandria, VA: ASCD

	Acquisition	
to use the techniques, skills, and modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	*KNOWLEDGE: Students will …* • K1 – Identify types of polygons including a square, rectangle, pentagon, hexagon, and octagon. U1, U2 • K2 – Differentiate between inscribed and circumscribed shapes. U1, U2 • K3 – Identify and differentiate geometric constructions and constraints (such as horizontal lines, vertical lines, parallel lines, perpendicular lines, colinear points, tangent lines, tangent circles, and concentric circles) and the results when applied to sketch features within a 3D solid modeling environment. U1, U2, U3 • K4 – Distinguish between the meanings of the terms weight and mass. U2 • K5 – Define the term “physical property” and identify the properties of length, volume, mass, weight, density, and surface area as physical properties. U2 • K6 – Identify three-dimensional objects generated by rotations of two-dimensional shapes and vice-versa. U1	*SKILLS: Students will …* • S1 – Solve real world and mathematical problems involving area and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, right prisms, cylinders, and spheres. U1, U2 • S2 – Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings using appropriate geometric and dimensional constraints and model features. U1, U3 • S3 – Measure mass with accuracy using a scale and report the measurement using an appropriate level of precision. U2 • S4 – Measure volume with accuracy and report the measurement with an appropriate level of precision. U2 • S5 – Calculate a physical property indirectly using available data or perform appropriate measurements to gather the necessary data (e.g., determine area or volume using linear measurements or determine density using mass and volume measurements). U2 • S6 – Solve volume problems using volume formulas for rectangular solids, cylinders, pyramids, cones, and spheres. U2 • S7 – Use physical properties to solve design problems (e.g., design an object or structure to satisfy physical constraints or minimize cost). U2 • S8 – Assign a specific material (included in the software library) to a part and use the capabilities of the CAD software to determine the mass, volume, and surface area of an object for which a 3D solid model has been created.U2, U3 • S9 – Assign a density value to a new material (not included in the software library) and apply the material to a 3D solid model within CAD software in order to determine the physical properties of the object. U2, U3

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Journal Entry: Essential Question 2	Teacher considers student responses and preconceptions in order to inform effective teaching	
A5.1 Calculating Properties of Shapes	• Peers compare answers for task #10	• Conclusion Questions
A5.2a Geometric Constraints		• Conclusion Questions
A5.2b Introduction to CAD Modeling Skills	• Conclusion Questions	
P5.3 Determining Density	• Peers compare answers and make corrections to Extend your learning task responses.	• Conclusion Questions • Determine density of teacher supplied object made of unknown material and make prediction of material.
A5.4 Calculating Properties of Solids	• Peers compare answers and make corrections to all tasks	• Conclusion Questions
A5.5a CAD Model Features Part 1	• Peer review and comparison of 3D model(s) including physical properties	• Conclusion Questions
A5.5b CAD Model Features Part 2	• Peer review and comparison of 3D model(s) including physical properties	• Conclusion Questions

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
A5.1 Calculating Properties of Shapes	K1, K2, S1, S2
A5.2a Geometric Constraints	K1, K3, S2
A5.2b Introduction to CAD Modeling Skills	K1, K2, K3, S2
P5.3 Determining Density	K4, S3, S4, S5, S6
A5.4 Calculating Properties of Solids	K4, K5, S1, S5,S6, S7
A5.5a CAD Model Features Part 1	K3, K6, S2
A5.5b CAD Model Features Part 2	K3, S2

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A5.6 Physical Property Analysis	• Peers compare answers, identify errors and correct mistakes	• Construct teacher generated 3D model and answer questions similar to those for Examples 1, 2, and 3 • Conclusion Questions
Small Group/Class Discussion: Essential Questions 2 and 3	Teacher considers student responses and preconceptions in order to inform effective teaching	
A5.7 Instant Challenge: Choremaster	• Conclusion Questions	
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

A5.6 Physical Property Analysis	S5, S7, S6, S7, S8, S9
A5.7 Instant Challenge: Choremaster	K1 (Unit 1), S2 (Unit 1), S3 (Unit 1)

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 5 – Geometry of Design

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Use current engineering tools (ex., spreadsheet software, CADD software) to create models, solve problems and perform engineering design.
• T2 – Apply geometric concepts and methods to describe and model objects and solve problems.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Geometric shapes and forms are described and differentiated by their characteristic features.
• U2 – Physical properties of objects are used to describe and model objects and can be used to define design requirements, as a means to compare potential solutions to a problem, and as a tool to specify final solutions.
• U3 – Computer aided design (CAD) and drafting software packages incorporate the application of a variety of geometric and dimensional constraints and model features to accurately represent objects.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• EQ1 – What advantage(s) do Computer Aided Design (CAD) and Drafting provide over traditional paper and pencil design? What advantages does paper and pencil design provide over CAD?
• EQ2 – Which high school math topic/course, Algebra or Geometry, is more closely related to engineering? Justify your answer.
• EQ3 – How does the material chosen for a product impact the design of the product?</td></tr>
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	Acquisition	
to use the techniques, skills, and modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	*KNOWLEDGE: Students will …* • K1 – Identify types of polygons including a square, rectangle, pentagon, hexagon, and octagon. U1, U2 • K2 – Differentiate between inscribed and circumscribed shapes. U1, U2 • K3 – Identify and differentiate geometric constructions and constraints (such as horizontal lines, vertical lines, parallel lines, perpendicular lines, colinear points, tangent lines, tangent circles, and concentric circles) and the results when applied to sketch features within a 3D solid modeling environment. U1, U2, U3 • K4 – Distinguish between the meanings of the terms weight and mass. U2 • K5 – Define the term "physical property" and identify the properties of length, volume, mass, weight, density, and surface area as physical properties. U2 • K6 – Identify three-dimensional objects generated by rotations of two-dimensional shapes and vice-versa. U1	*SKILLS: Students will …* • S1 – Solve real world and mathematical problems involving area and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, right prisms, cylinders, and spheres. U1, U2 • S2 – Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings using appropriate geometric and dimensional constraints and model features. U1, U3 • S3 – Measure mass with accuracy using a scale and report the measurement using an appropriate level of precision. U2 • S4 – Measure volume with accuracy and report the measurement with an appropriate level of precision. U2 • S5 – Calculate a physical property indirectly using available data or perform appropriate measurements to gather the necessary data (e.g., determine area or volume using linear measurements or determine density using mass and volume measurements). U2 • S6 – Solve volume problems using volume formulas for rectangular solids, cylinders, pyramids, cones, and spheres. U2 • S7 – Use physical properties to solve design problems (e.g., design an object or structure to satisfy physical constraints or minimize cost). U2 • S8 – Assign a specific material (included in the software library) to a part and use the capabilities of the CAD software to determine the mass, volume, and surface area of an object for which a 3D solid model has been created.U2, U3 • S9 – Assign a density value to a new material (not included in the software library) and apply the material to a 3D solid model within CAD software in order to determine the physical properties of the object. U2, U3

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Journal Entry: Essential Question 2	Teacher considers student responses and preconceptions in order to inform effective teaching	
A5.1 Calculating Properties of Shapes	• Peers compare answers for task #10	• Conclusion Questions
A5.2a Geometric Constraints		• Conclusion Questions
A5.2b Introduction to CAD Modeling Skills	• Conclusion Questions	
P5.3 Determining Density	• Peers compare answers and make corrections to Extend your learning task responses.	• Conclusion Questions • Determine density of teacher supplied object made of unknown material and make prediction of material.
A5.4 Calculating Properties of Solids	• Peers compare answers and make corrections to all tasks	• Conclusion Questions
A5.5a CAD Model Features Part 1	• Peer review and comparison of 3D model(s) including physical properties	• Conclusion Questions
A5.5b CAD Model Features Part 2	• Peer review and comparison of 3D model(s) including physical properties	• Conclusion Questions

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
A5.1 Calculating Properties of Shapes	K1, K2, S1, S2
A5.2a Geometric Constraints	K1, K3, S2
A5.2b Introduction to CAD Modeling Skills	K1, K2, K3, S2
P5.3 Determining Density	K4, S3, S4, S5, S6
A5.4 Calculating Properties of Solids	K4, K5, S1, S5,S6, S7
A5.5a CAD Model Features Part 1	K3, K6, S2
A5.5b CAD Model Features Part 2	K3, S2

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A5.6 Physical Property Analysis	• Peers compare answers, identify errors and correct mistakes	• Construct teacher generated 3D model and answer questions similar to those for Examples 1, 2, and 3 • Conclusion Questions
Small Group/Class Discussion: Essential Questions 2 and 3	Teacher considers student responses and preconceptions in order to inform effective teaching	
A5.7 Instant Challenge: Choremaster	• Conclusion Questions	
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

A5.6 Physical Property Analysis	S5, S7, S6, S7, S8, S9
A5.7 Instant Challenge: Choremaster	K1 (Unit 1), S2 (Unit 1), S3 (Unit 1)

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 5 – Geometry of Design

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Use current engineering tools (ex., spreadsheet software, CADD software) to create models, solve problems and perform engineering design.
• T2 – Apply geometric concepts and methods to describe and model objects and solve problems.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Geometric shapes and forms are described and differentiated by their characteristic features.
• U2 – Physical properties of objects are used to describe and model objects and can be used to define design requirements, as a means to compare potential solutions to a problem, and as a tool to specify final solutions.
• U3 – Computer aided design (CAD) and drafting software packages incorporate the application of a variety of geometric and dimensional constraints and model features to accurately represent objects.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• EQ1 – What advantage(s) do Computer Aided Design (CAD) and Drafting provide over traditional paper and pencil design? What advantages does paper and pencil design provide over CAD?
• EQ2 – Which high school math topic/course, Algebra or Geometry, is more closely related to engineering? Justify your answer.
• EQ3 – How does the material chosen for a product impact the design of the product?</td></tr>
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	Acquisition	
to use the techniques, skills, and modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	*KNOWLEDGE: Students will …* • K1 – Identify types of polygons including a square, rectangle, pentagon, hexagon, and octagon. U1, U2 • K2 – Differentiate between inscribed and circumscribed shapes. U1, U2 • K3 – Identify and differentiate geometric constructions and constraints (such as horizontal lines, vertical lines, parallel lines, perpendicular lines, colinear points, tangent lines, tangent circles, and concentric circles) and the results when applied to sketch features within a 3D solid modeling environment. U1, U2, U3 • K4 – Distinguish between the meanings of the terms weight and mass. U2 • K5 – Define the term "physical property" and identify the properties of length, volume, mass, weight, density, and surface area as physical properties. U2 • K6 – Identify three-dimensional objects generated by rotations of two-dimensional shapes and vice-versa. U1	*SKILLS: Students will …* • S1 – Solve real world and mathematical problems involving area and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, right prisms, cylinders, and spheres. U1, U2 • S2 – Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings using appropriate geometric and dimensional constraints and model features. U1, U3 • S3 – Measure mass with accuracy using a scale and report the measurement using an appropriate level of precision. U2 • S4 – Measure volume with accuracy and report the measurement with an appropriate level of precision. U2 • S5 – Calculate a physical property indirectly using available data or perform appropriate measurements to gather the necessary data (e.g., determine area or volume using linear measurements or determine density using mass and volume measurements). U2 • S6 – Solve volume problems using volume formulas for rectangular solids, cylinders, pyramids, cones, and spheres. U2 • S7 – Use physical properties to solve design problems (e.g., design an object or structure to satisfy physical constraints or minimize cost). U2 • S8 – Assign a specific material (included in the software library) to a part and use the capabilities of the CAD software to determine the mass, volume, and surface area of an object for which a 3D solid model has been created.U2, U3 • S9 – Assign a density value to a new material (not included in the software library) and apply the material to a 3D solid model within CAD software in order to determine the physical properties of the object. U2, U3

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Journal Entry: Essential Question 2	Teacher considers student responses and preconceptions in order to inform effective teaching	
A5.1 Calculating Properties of Shapes	• Peers compare answers for task #10	• Conclusion Questions
A5.2a Geometric Constraints		• Conclusion Questions
A5.2b Introduction to CAD Modeling Skills	• Conclusion Questions	
P5.3 Determining Density	• Peers compare answers and make corrections to Extend your learning task responses.	• Conclusion Questions • Determine density of teacher supplied object made of unknown material and make prediction of material.
A5.4 Calculating Properties of Solids	• Peers compare answers and make corrections to all tasks	• Conclusion Questions
A5.5a CAD Model Features Part 1	• Peer review and comparison of 3D model(s) including physical properties	• Conclusion Questions
A5.5b CAD Model Features Part 2	• Peer review and comparison of 3D model(s) including physical properties	• Conclusion Questions

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
A5.1 Calculating Properties of Shapes	K1, K2, S1, S2
A5.2a Geometric Constraints	K1, K3, S2
A5.2b Introduction to CAD Modeling Skills	K1, K2, K3, S2
P5.3 Determining Density	K4, S3, S4, S5, S6
A5.4 Calculating Properties of Solids	K4, K5, S1, S5,S6, S7
A5.5a CAD Model Features Part 1	K3, K6, S2
A5.5b CAD Model Features Part 2	K3, S2

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A5.6 Physical Property Analysis	• Peers compare answers, identify errors and correct mistakes	• Construct teacher generated 3D model and answer questions similar to those for Examples 1, 2, and 3 • Conclusion Questions
Small Group/Class Discussion: Essential Questions 2 and 3	Teacher considers student responses and preconceptions in order to inform effective teaching	
A5.7 Instant Challenge: Choremaster	• Conclusion Questions	
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

A5.6 Physical Property Analysis	S5, S7, S6, S7, S8, S9
A5.7 Instant Challenge: Choremaster	K1 (Unit 1), S2 (Unit 1), S3 (Unit 1)

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Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 6 – Reverse Engineering

Desired Results *(stage 1)*

ESTABLISHED GOALS
It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability to use the techniques, skills, and

Transfer

TRANSFER: Students will be able to independently use their learning to …

- T1 – Communicate technical information or ideas in multiple formats including orally, graphically, textually and mathematically, as appropriate.
- T2 – Plan and conduct an investigation or test a design to gather data to document a design, build and revise models, and/or solve a problem.

Meaning

UNDERSTANDINGS: Students will understand that …

- U1 – Reverse engineering involves disassembling and analyzing a product or system in order to understand and document the visual, functional, and/or structural aspects of its design.
- U2 – Visual elements and principles of design are part of an aesthetic vocabulary that is used to describe the visual characteristics of an object, the application of which can affect the visual appeal of the object and its commercial success in the marketplace.
- U3 – Technical professionals use the results of reverse engineering for many different purposes such as discovery, testing, forensics, improvement or redesign, and producing technical documentation of a product.
- U3 (Unit 1) – Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms.

ESSENTIAL QUESTIONS: Students will keep considering …

- Q1 – Why are many consumer product designs not commercially successful?
- Q2 – When, if ever, is it acceptable for a company to reverse engineer and reproduce a successful consumer product designed by another person/company?

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<table>
<tr>
<td rowspan="3">
modern engineering tools necessary for engineering practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.
</td>
<td>• U4 (Unit 1) – Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.</td>
<td></td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>
KNOWLEDGE: Students will …
• K1 – Identify and describe the visual principles and elements of design apparent in a natural or man-made object. U1, U2
• K2 – Describe the process of reverse engineering. U1, U2
• K3 – Explain the various reasons to perform reverse engineering including discovery, documentation, investigation, and product improvement. U1, U3
</td>
<td>
SKILLS: Students will …
• S1 – Explain how the visual elements and principles of design affect the aesthetics and commercial success of a product. U1, U2
• S2 – Perform a functional analysis of a product in order to determine the purpose, inputs and outputs, and the operation of a product or system. U1
• S3 – Perform a structural analysis of a product in order to determine the materials used and the form of component parts as well as the configuration and interaction of component parts when assembled (if applicable). U1
• S4 – Select and utilize technology (software and hardware) to create high impact visual aids. U3 (Unit 1), U4, (Unit 1)
</td>
</tr>
</table>

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Activity 6.1 Elements and Principles of Design Identification	• Peer assessment of visual analysis	• Conclusion Questions
Activity 6.2 Visual Analysis Automoblox		• Assessment of visual analysis • Conclusion Questions
Activity 6.2a Visual Analysis ALTERNATE		• Assessment of visual analysis • Conclusion Questions
Project 6.3 Functional Analysis Automoblox	• Peers compare black box model	• Conclusion Questions
Project 6.3a Functional Analysis ALTERNATE	• Peers compare black box model	• Conclusion Questions
Small Group/Class Discussion: Essential Question 2	• Teacher considers student responses and preconceptions in order to inform effective teaching	
Activity 6.4 Structural Analysis Automoblox	• Peers compare answers to #4 and #5	• Conclusion Questions
Activity 6.4a Product Disassembly ALTERNATE	• Peers compare answers responses	• Conclusion Questions
Journal Entry: Essential Question 1		• Teacher assesses student responses
Activity 6.5 Product Reverse Engineering Presentation		• P6.5 Rubric • Conclusion Questions
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
Activity 6.1 Elements and Principles of Design Identification	K1, S1
Activity 6.2 Visual Analysis Automoblox	K1, S1
Activity 6.2a Visual Analysis ALTERNATE	K1, S1
Project 6.3 Functional Analysis Automoblox	K2, K3, S2
Project 6.3a Functional Analysis ALTERNATE	K2, K3, S2
Activity 6.4 Structural Analysis Automoblox	K2, S3, S3
Activity 6.4a Product Disassembly ALTERNATE	K2, S3
Activity 6.5 Product Reverse Engineering Presentation	K1, K2, S1, S4

Format guided by: Wiggins, G. & McTighe, J. (2011). The understanding by design guide to creating high quality units. Alexandria, VA: ASCD

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 7 – Documentation

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Define a design problem that involves criteria and constraints that may include social, technical and/or environmental considerations. T2 – Use the engineering design process to design a system, component, or process to meet desired needs within realistic constraints.
• T3 – Communicate technical information or ideas in multiple formats including orally, graphically, textually and mathematically, as appropriate.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Specific notes (such as hole and thread notes), and general notes (such as general tolerances) in combination with dimensions are included on technical drawings according to accepted practice and an established set of standards so as to convey size and location information about detailed parts, their features, and their configuration in assemblies.
• U2 – Computer aided drafting and design (CAD) software packages facilitate virtual modeling of assemblies and the creation of technical drawings. They are used to efficiently and accurately detail assemblies according to standard engineering practice.
• U3 – A degree of variation always exists between specified dimensions and the measurement of a manufactured object which is controlled by the use of</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 -- What are the consequences to the final solution if the design problem is poorly communicated?
• Q2 – How does one know that a given design solution is the best possible solution?
• Q3 – Engineering is described as the application of math, science and technology to solve problems. Does this description imply that designing an enhancement to an Automoblox vehicle is the work of an engineer? Justify your answer.
• Q4 – What quality makes a set of drawings sufficient to adequately represent the design intent?
• Q5 – Is it always necessary to indicate a tolerance for every dimension on a technical drawing? Justify your answer.
• Q6 -- Stephen Covey includes Begin with the End in Mind</td></tr>
</table>

necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	tolerances on technical drawings. • U4 – A problem and the requirements for a successful solution to the problem should be clearly communicated and justified. • U5 – A solution path is selected and justified by evaluating and comparing competing design solutions based on jointly developed and agreed-upon design criteria and constraints. • U1 (Unit1) – Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing. • U4 (unit 1) – The style of the engineering graphics and the type of drawings views used to detail an object vary depending upon the intended use of the graphic.	as one of the seven habits listed in his book The 7 Habits of Highly Effective People. How can this habit make an engineer more effective? • Q7- In your opinion which step of the design process is most important to successfully innovate or invent a new product? Justify your answer.
	KNOWLEDGE: Students will … • K1 – Identify and differentiate between size dimensions and location dimensions. U1, U1 (Unit 1) • K2 – Identify and correctly apply chain dimensioning or datum dimensioning methods to a technical drawing. U1, U1 (Unit 1) • K3 – Identify dimensioning standards commonly used in technical drawing. U1, U1 (Unit 1) • K4 – Identify the shapes of two-dimensional cross sections of three dimensional objects. U6 • K5 – Identify, define and explain the proper use of a section view in technical drawing. U1 (unit 1), U4 (Unit 1) • K6 – Read and interpret a hole note to identify the size and type of hole including through, clearance, blind,	*SKILLS: Students will …* • S1 – Hand sketch a scaled full or half section view in the correct orientation to fully detail an object or part given the actual object, a detailed verbal description of the object, a pictorial view of the object, or a set of orthographic projections. U1 (Unit 1), U4 (Unit 1) • S2 – Generate section views using CAD according to standard engineering practice. U1, U2, U1 (Unit 1) • S3 – Dimension a section view of a simple object or part according to a set of dimensioning standards and accepted practices. U1, U2, U1 (Unit1) • S4 – Annotate (including specific and general notes) working drawings according to accepted engineering practice. Include dimensioning according to a set of dimensioning rules, proper hole and thread notes, proper tolerance annotation, and the inclusion of other notes necessary to fully describe a part according to standard

	counter bore, and countersink holes. U1, U1 (Unit 1) • K7 – Identify and differentiate among limit dimensions, a unilateral tolerance, and a bilateral tolerance. U3 • K8 – Differentiate between clearance and interference fit. U3 • K9 – Explain each assembly constraint (including mate, flush, insert, and tangent), its role in an assembly model, and the degrees of freedom that it removes from the movement between parts. U2	engineering practice. U1, U2, U1 (Unit 1) • S5 – Create specific notes on a technical drawing to convey important information about a specific feature of a detailed object, and create general notes to convey details that pertain to information presented on the entire drawing (such as units, scale, patent details, etc.). U1, U2, U1 (Unit 1) • S6 – Model and annotate (with a hole note) through, clearance, blind, counter bore, and countersink holes. U1, U2, U1 (Unit 1) • S7 – Compare the effect of chain dimensioning and datum dimensioning on the tolerance of a particular specified dimension. U1, U3 • S8 – Determine the specified dimension, tolerance, upper limit, and lower limit for any given dimension and related tolerance (or any distance that is dependent on given dimensions) shown on a technical drawing. U1, U1, U3 • S9 – Determine the allowance between two mating parts of an assembly based on dimensions given on a technical drawing. • S10 – Identify the type of fit given a drawing, a description, or a physical example of two mating parts. U1, U3, U1 (Unit) • S11 – Create assemblies of parts in CAD and use appropriate assembly constraints to create an assembly that allows correct realistic movement among parts. Manipulate the assembly model to demonstrate the movement. U2 • S12 – Create a CAD assembly drawing. Identify each component of the assembly with identification numbers and create a parts list to detail each component using CAD. U1, U2 • S13 – Analyze information gathered during reverse engineering to identify shortcoming of the design and/or opportunities for improvement or innovation. U7, U14 • S14 – Define and justify a design problem and express

		the concerns, needs, and desires of the primary stakeholders. U4 • S15 –Present and justify design specifications, and clearly explain the criteria and constraints associated with a successful design solution. U4 • S16–Write a design brief to communicate the problem, problem constraints, and solution criteria. U4 • S17 – Support design ideas using a variety of convincing evidence. U5 • S18 – Jointly develop a decision matrix based on accepted outcome criteria and constraints. U5 • S19 – Clearly justify and validate a selected solution path. U5 • S20 – Create a set of working drawings to detail a design project. U1, U2, U1 (Unit 1)

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Activity 7.1 More Dimensioning	• Peer assessment of dimensioning per #6	• Conclusion Questions • Create dimensioned drawings of teacher provided pat similar to those included in activity
Activity 7.2 Sectional Views	• Peer review of #6 prior to completing #7	• Conclusion Questions • Sketch section view of teacher provided part (e.g. tape dispenser)
Activity 7.3 Tolerances	• Self-assessment based on correct answers provided by teacher • Correction of responses and self-reflection/journal entry as to why responses were incorrect	• Conclusion Questions
Journal Entry: Essential Question 5		• Teacher assesses student responses
Project 7.4 Assembly Model	• Peer/teacher assessment of assembly models	• Conclusion Questions
Project 7.5 Engineering Documentation Automoblox	• Self/Peer assessment using P7.5 Rubric	• Conclusion Questions • P7.5 Rubric

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
Activity 7.1 More Dimensioning	K1, K2, S1, S2, S4
Activity 7.2 Sectional Views	K3, K4, K5 ,K6 S1, S2, S3, S4, S5, S6
Activity 7.3 Tolerances	K6, K7, K8, S6, S7, S8, S9
Project 7.4 Assembly Model	K9, S10, S11
Project 7.5 Engineering Documentation Automoblox	S12, S19

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Project 7.5a Engineering Documentation ALTERNATE	• Self/Peer assessment using P7.5 Rubric	• Conclusion Questions • P7.5 Rubric
Project 7.6 Design Brief (Apollo 13)	• Conclusion Questions	
Small Group/Class Discussion: Essential Question 1, 2, and/or 4	• Teacher considers student responses and preconceptions in order to inform effective teaching	
Journal Entry: Essential Question 6		• Teacher assesses student responses
Problem 7.7 Automoblox Product Enhancement	• Conclusion Questions	• Design Problem Rubric
Small Group/Class Discussion: Essential Question 3	• Teacher considers student responses and preconceptions in order to inform effective teaching	
Journal Entry: Essential Question 7		• Teacher assesses student responses
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

Project 7.5a Engineering Documentation ALTERNATE	S12, S19
Project 7.6 Design Brief (Apollo 13)	S13, S14, S15
Problem 7.7 Automoblox Product Enhancement	S1, S2, S4, S8, S9,S12, S13, S14, S15, S16, S17, S18, S19

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 8 – Advanced Computer Modeling

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER:Students will be able to independently use their learning to …

• T1 – Use mathematical and computational thinking to represent phenolmenon and solve engineering problems.
• T2 -- Use current engineering tools (ex., spreadsheet software, CADD software) to create models, solve problems and perform engineering design.
• T3 – Communicate technical information or ideas in multiple formats including orally, graphically, textually and mathematically, as appropriate.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Parametric computer aided design (CAD) software packages facilitate 3D virtual modeling of parts and assemblies using parameters, such as geometric constraints (the relationships between geometric entities) as well as numeric constraints (dimensions) used to determine the shape and size of geometry and models.
• U2 – A parametic numeric constraint (dimension) can be represented by a function (equation) that mathimatically describes the relationship between that dimension and other related dimension(s).
• U1 (Unit1) – Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – Are working drawings always necessary in order to communicate the design of a consumer product? Justify your answer.
• Q2 – Animated assemblies are not typically included as part of the technical documentation of a design. How can 3D animated assembly models of an object or a proposed design be used in the design process? Beyond the design process?</td></tr>
</table>

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<table>
<tr>
<td rowspan="3">

G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
G7 – Demonstrate an understanding of professional and ethical responsibility.
G8 – Demonstrate an ability to function on multidisciplinary teams.
G9 – Demonstrate an ability to communicate effectively.
G10 – Gain knowledge of contemporary issues.
G11 – Recognize the need for, and develop an ability to engage in life-long learning.

</td>
<td>

U4 (unit 1) – The style of the engineering graphics and the type of drawings views used teo detail an object vary depending upon the intended use of the graphic.

</td>
<td></td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>
KNOWLEDGE: Students will …

K1 – Identify, define, and explain the proper use of an auxiliary view in technical drawing. U1 (unit 1), U4 (Unit 1)

</td>
<td>
SKILLS: Students will …

S1 – Use advanced modeling features to create three-dimensional solid models of complex parts and assemblies within CAD and with little guidance given the actual part using appropriate geometric and dimensional constraints. U1
S2 – Formulate equations and inequalities to represent relationships between quantities. U2
S3 – Using a CAD application, create relationships among part features and dimensions using parametric formulas. U1, U2, U3
S4 – Create an exploded assembly view of a multip-part product. Identify each component of the assembly with identification numbers and create a parts list to detail each component using CAD. U1
S5 – Perform a peer review of technical drawings and offer constructive feedback based on standard engineering practices. U1, U1(Unit 1)
S6 (Optional) – Hand sketch an auxiliary view in the correct orientation to fully detail an object or part given the actual object, a detailed verbal description of the object, a pictorial view of the object, or a set of orthographic projections. U1 (Unit 1), U4 (Unit 1)
S7 (Optional) – Generate an auxiliary view using CAD according to standard engineering practice. U1 (Unit 1), U4 (unit 1)

</td>
</tr>
</table>

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Project 8.1 Model Button Maker	• Conclusion Questions • Peer comparison of physical properties of parts	
Project 8.1a Model Miniature Train (Optional)	• Conclusion Questions • Peer comparison of physical properties of parts	
Activity 8.2 Parametric Constraints	• Conclusion Questions	• Completion of #3 Optional task
Activity 8.2a Parametric Constraints Practice (Optional)		• Ask students to justify their work in verbal or written form
Activity 8.3 Auxiliary Views (Optional)	• Peer assessment and then revision of activity tasks	• Assessment of task #3 • Conclusion Quesitons
Small Group/Class Discussion: Essential Question 1	• Teacher considers student responses and preconceptions in order to inform effective teaching	
Activity 8.4 Working Drawings (Button Maker)	• Self-evaluation and/or peer evaluation using A8.4 Rubric	• A8.4 Rubric • Conclusion Questions
Activity 8.4a Working Drawings Miniature Train (Optional)	• Self-evaluation and/or peer evlatuation of activity tasks	• Conclusion Questions
Journal Entry: Essential Question 2		• Teacher assesses student responses
Activity 8.5 Instant Challenge: Air Vehicle		• Conclusion Questions
Unit Assessment Items	• All items	• All items

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
Project 8.1 Model Button Maker	S1
Project 8.1a Model Miniature Train (Optional)	S1
Activity 8.2 Parametric Constraints	K1, S1, S2, S3
Activity 8.2a Parametric Constraints Practice (Optional)	(K1, S2, S3)
Activity 8.3 Auxiliary Views (Optional)	(K1, S6, S7)
Activity 8.4 Working Drawings (Button Maker)	S1, S4, S5
Activity 8.4a Working Drawings Miniature Train (Optional)	(K1, S1, S4, S6, S7)
Activity 8.5 Instant Challenge: Air Vehicle	K1 (Unit 1), S2 (Unit 1), S3 (Unit 1)

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Summative – EoC		• All items		

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 9 – Design Team

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Communicate effectively using virtual/remote communication tools.
• T2 – Function effectively on a multidisciplinary team.
• T3 – Perform research to gather information, define problems, provide evidence, and/or justify decisions in the process of solving a problem.
• T4 – Apply the design process to design a system, component, or process to meet desired needs within realistic constraints. T5 – Understand professional and ethical responsibilities related to engineering.
• T6 – Communicate technical information or ideas in multiple formats including orally, graphically, textually and mathematically, as appropriate.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Engineering has a global impact on society and the environment.
• U2 – Research derived from a variety of sources (including subject matter experts) is used to facilitate effective development and evaluation of a design problem and a successful solution to the problem.
• U3 – Specific oral communication techniques are used to effectively convey information and communicate with an audience.
• U4 – Engineering design and practices are governed by ethics, values, and laws.
• U5 – Effective design teams can improve the efficiency</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 -- Is it ever advantageous to create a design or solve a problem individually as opposed to using a team approach? Explain.
• Q2 – What strategy would you use to form a design team in order to obtain the best solution possible?
• Q3 -- What does it mean to be “ethical” in your work? Do engineers need to be taught to be “ethical”?
• Q4 -- It has been said that, “Having a vision without action is a daydream; Taking action without a vision is a nightmare!” How does this apply to engineering design?</td></tr>
</table>

modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	and effectiveness of the design process. • U6 – Virtual design teams include people in different locations who collaborate using communication methods other than face-to-face contact. • U7 – In order to be an effective team member, one must demonstrate positive team behaviors and act according to accepted norms, contribute to group goals according to assigned roles, and use appropriate conflict resolution strategies. • U8 – Styles and modes of professional correspondence are tailored to the type of audience and intended goals. • U9 – Project planning tools and management skills are often used in the process of solving engineering design problems.	
	KNOWLEDGE: *Students will …* • K1 – Identify and describe the steps of a typical product lifecycle (including raw material extraction, processing, manufacture, use and maintenance, and disposal). U1 • K2 – Identify and explain how the basic theories of ethics relate to engineering. U4 • K3 – Identify team member skill sets needed to produce an effective team. U6 • K4 – Define the term group norms and discuss the importance of norms in creating an effective team environment.U5, U7 • K5 – Identify the advantages and disadvantages of virtual design teams compared to traditional design teams. U5, U6	***SKILLS:*** *Students will …* • S1 – Assess the development of an engineered product and the impact of the product on society and the environment. U1 • S2 – Utilize research tools and resources (such as the Internet; media centers; market research; professional journals; printed, electronic, and multimedia resources; etc.) to validate design decisions and justify a problem solution. U2 • S3 – Summarize key ideas in information sources including scientific and engineering texts, tables, diagrams, and graphs. U2 • S4 – Deliver organized oral presentations of work tailored to the audience. U3 • S5 – Organize and express thoughts and information in a clear and concise manner. U6 • S6 – Participate on a virtual team using remote collaboration tools to support team collaboration and

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		problem solving. U5, U6, U7 • S7 – Identify appropriate technology to support remote collaboration among virtual design team members (such as asynchronous communications, audio and video conferencing, instant messaging, synchronous file editing, and file transfer). U6 • S8 – Demonstrate positive team behaviors and contribute to a positive team dynamic. U7 • S9 -- Contribute equitably to the attainment of group goals based on assigned roles. U1, U11, U12 • S10 – Practice appropriate conflict resolution strategies within a team environment. U1, U11, U12 • S11 – Identify an appropriate mode of two-way communication based on the audience and intended goal of the communication. U8 • S12 –Use an appropriate and professional tone and vernacular based on the audience of the correspondence. U8 • S13 –Document correspondence and conversations in an accurate and organized manner. U8 • S14 – Create and utilize a Gantt chart to plan, monitor, and control task completion during a design project. U9 • S15 – Adjust voice and writing style to align with audience and purpose. U3 • S16 – Deliver organized oral presentations of work tailored to the audience. U3

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
A 9.1 Product Lifecycle	• Self/peer-evaluation using A9.1 • Conclusion Questions	• A9.1 Rubric • Conclusion Questions

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
A 9.1 Product Lifecycle	K1, S1, S2, S3, S4

B9.2 Engineering Design Ethics Design Brief	• Peer assessment of deliverables	• Conclusion Questions
Journal Entry: Essential Question 3		• Teacher assesses student responses
P9.3 Virtual Design Challenge	• A9.3.d Periodic Teammate Evaluation • A9.3.e Periodic Self Evaluation	• Multiple rubrics • Conclusion Questions
A9.4 Team Norms		• Conclusion Questions
Small Group/Class Discussion: Essential Questions 1 and/or 2	• Teacher considers student responses and preconceptions in order to inform effective teaching	
A9.5 Product Research Documentation	• Teacher questioning and student verbal justification of the product choices	
Journal Entry: Essential Question 4		• Teacher assesses student responses
Unit Assessment Items	• All items	• All items
Summative – EoC		• All items

B9.2 Engineering Design Ethics Design Brief	K2, S1, S2, S3, S5
P9.3 Virtual Design Challenge	S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16
A9.4 Team Norms	K3, K4, S8, S9
A9.5 Product Research Documentation	S2, S3

Curriculum Framework – Introduction to Engineering Design (2015-2016)
Unit 10 – Design Challenges

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="6">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Apply the design process to design a system, component, or process to meet desired needs within realistic constraints.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 (Unit 1) – An engineering design process involves a characteristic set of practices and steps used to develop innovative solutions to problems.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• EQ1 – Engineering has been referred to as the “stealth” profession. Do you think this is an appropriate label? Explain.
• EQ2 – If you had to describe one strategy that would most help an engineer be a good and effective designer, what would it be?</td></tr>
<tr><th colspan="2">Acquisition</th></tr>
<tr><td>KNOWLEDGE: Students will …

• K1 – Identify the steps in an engineering design process and describe the activities involved in each step of the process. U1</td><td>SKILLS: Students will …

• S1 – Develop and document an effective solution to a problem that meets specific design requirements. U1
• S2 – Document and describe the design process used in the solution of a problem and reflect on all steps of the design process. U1</td></tr>
</table>

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necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.		

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B) (U/L level)	Assessment FOR Learning	Assessment OF Learning
Project 10.1 Design Challenges	• Self/Peer review or evaluation prior to final submittal	• P10.1 Rubric • Conclusion Questions
Small Group/Class Discussion: Essential Question 1	• Teacher considers student responses and preconceptions in order to inform effective teaching	
Journal Entry: Essential Question 2		• Teacher assesses student responses

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems (B)	Knowledge and Skills
Project 10.1 Design Challenges	K1, S1, S2

Unit 1 Key Terms

Key Term	Definition
Assess	To thoroughly and methodically analyze accomplishment against specific goals and criteria.
Assessment	An evaluation technique for technology that requires analyzing benefits and risks, understanding the trade-offs, and then determining the best action to take in order to ensure that the desired positive outcomes outweigh the negative consequences. Techniques used to analyze accomplishments against specific goals and criteria. Examples of assessments include tests, surveys, observations, and self-assessment.
Brainstorm	A group technique for solving problems, generating ideas, stimulating creative thinking, etc. by unrestrained spontaneous participation in discussion.
Client	A person using the services of a professional person or organization.
Creativity	The ability to make or bring a new concept or idea into existence; marked by the ability or power to create.
Criteria	A means of judging. A standard, rule, or test by which something can be judged.
Constraint	1. A limit to a design process. Constraints may be such things as appearance, funding, space, materials, and human capabilities. 2. A limitation or restriction.
Design	1. An iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants or solve problems. 2. A plan or drawing produced to show the look and function or workings of something before it is built or made. 3. A decorative pattern.
Design Brief	A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.
Design Process	A systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants and to winnow (narrow) down the possible solutions to one final choice.
Design Statement	A part of a design brief that challenges the designer, describes what a design solution should do without describing how to solve the problem, and identifies the degree to which the solution must be executed.
Designer	A person who designs any of a variety of things. This usually implies the task of creating drawings or in some ways uses visual cues to organize his or her work.

Engineer	A person who is trained in and uses technological and scientific knowledge to solve practical problems.
Engineering Notebook	A book in which an engineer will formally document, in chronological order, all of his/her work that is associated with a specific design project.
Innovation	An improvement of an existing technological product, system, or method of doing something.
Invention	A new product, system, or process that has never existed before, created by study and experimentation.
Iterative	A process that repeats a series of steps over and over until the desired outcome is obtained.
Justifiable	Capable of being shown as reasonable or merited according to accepted standards.
Piling-on	An idea that produces a similar idea or an enhanced idea.
Problem Identification	The recognition of an unwelcome or harmful matter needing to be dealt with.
Product	A tangible artifact produced by means of either human or mechanical work, or by biological or chemical process.
Prototype	A full-scale working model used to test a design concept by making actual observations and necessary adjustments.
Research	The systematic study of materials and sources in order to establish facts and reach new conclusions.
Valid	Well-founded on evidence and corresponds accurately to the real world.

Unit 2 Key Terms

Key Term	Definition
Cabinet Pictorial	Oblique pictorial where depth is represented as half scale compared to the height and width scale.
Cavalier Pictorial	Oblique pictorial where height, width, and depth are represented at full scale.
Center Line	A line which defines the center of arcs, circles, or symmetrical parts.
Construction Line	Lightly drawn lines to guide drawing other lines and shapes.
Depth	The measurement associated with an object's front-to-back dimension or extent of something from side to side.
Dimension	A measurable extent, such as the three principal dimensions of an object is width, height, and depth.
Dimension Line	A line which represents distance.
Documentation	1. The documents that are required for something or that give evidence or proof of something. 2. Drawings or printed information that contain instructions for assembling, installing, operating, and servicing.
Drawing	A formal graphical representation of an object containing information based on the drawing type.
Edge	The line along which two surfaces of a solid meet.
Ellipse	A regular oval shape, traced by a point moving in a plane so that the sum of its distances from two other points is constant, or resulting when a cone is cut by an oblique plane which does not intersect the base.
Extension Line	Line which represents where a dimension starts and stops.
Freehand	Sketching which is done manually without the aid of instruments such as rulers.
Grid	A network of lines that cross each other to form a series of squares or rectangles.
Height	The measurement associated with an object's top-to-bottom dimension.
Hidden Line	A line type that represents an edge that is not directly visible.
Isometric Sketch	A form of pictorial sketch in which all three drawing axes form equal angles of 120 degrees with the plane of projection.
Leader Line	Line which indicates dimensions of arcs, circles, and detail.
Line	1. A long thin mark on a surface. 2. A continuous extent of length, straight or curved, without breadth or thickness; the trace of a moving point. 3. Long, narrow mark or band.
Line Conventions	Standardization of lines used on technical drawings by line weight and style.
Line Weight	Also called line width. The thickness of a line, characterized as thick or thin.

Long-Break Line	A line which indicates that a very long objects with uniform detail is drawn foreshortened.
Manufacture	To make something, especially on a large scale using machinery.
Measurement	The process of using dimensions, quantity, or capacity by comparison with a standard in order to mark off, apportion, lay out, or establish dimensions.
Multiview Drawing	A drawing which contains views of an object projected onto two or more orthographic planes.
Object Line	A heavy solid line used on a drawing to represent the outline of an object.
Oblique Sketch	A form of pictorial in which an object is represented as true width and height, but the depth can be any size and drawn at any angle.
Orthographic Projection	A method of representing three-dimensional objects on a plane having only length and breadth. Also referred to as Right Angle Projection.
Perspective Sketch	A form of pictorial sketch in which vanishing points are used to provide the depth and distortion that is seen with the human eye.
Pictorial Sketch	A sketch that shows an object's height, width, and depth in a single view.
Plane	A flat surface on which a straight line joining any two points would wholly lie.
Point	A location in space.
Profile	An outline of an object when viewed from one side.
Projection Line	An imaginary line that is used to locate or project the corners, edges, and features of a three-dimensional object onto an imaginary two-dimensional surface.
Projection Plane	An imaginary surface between the object and the observer on which the view of the object is projected and drawn.
Proportion	1. The relationship of one thing to another in size, amount, etc. 2. Size or weight relationships among structures or among elements in a single structure.
Scale	1. A straight-edged strip of rigid material marked at regular intervals that is used to measure distances. 2. A proportion between two sets of dimensions used to develop accurate, larger or smaller prototypes, or models.
Section Lines	Thin lines used in a section view to indicate where the cutting plane line has cut through material.
Shading	The representation of light and shade on a sketch or map.
Short-Break Line	Line which shows where part is broken to reveal detail behind the part or to shorten a long continuous part.
Shape	A two-dimensional contour that characterizes an object or area, in contrast to three-dimensional form.
Sketch	A rough representation of the main features of an object or scene and often made as a preliminary study.
Solid	A three-dimensional body or geometric figure.

Technical Working Drawing	A drawing that is used to show the material, size, and shape of a product for manufacturing purposes.
Three-Dimensional	Having the dimensions of height, width, and depth.
Tone	The general effect of color or of light and shade in a picture.
Two-Dimensional	Having the dimensions of height and width, height and depth, or width and depth only.
Vanishing Point	A vanishing point is a point in space, usually located on the horizon, where parallel edges of an object appear to converge.
View	Colloquial term for views of an object projected onto two or more orthographic planes in a multiview drawing.
Width	The measurement associated with an object's side-to-side dimension.

Unit 3 Key Terms

Key Term	Definition
Accuracy	The degree of closeness of measurements of a quantity to the actual (or accepted) value.
Arrowheads	Arrowheads are used to indicate the end of a dimension line or leader.
Caliper	A measuring instrument having two adjustable jaws typically used to measure diameter or thickness.
Class Interval	A group of values that is used to analyze the distribution of data.
Convert	To change money, stocks, or units in which a quantity is expressed into others of a different kind.
Data	Facts and statistics used for reference or analysis.
Data Set	A group of individual values or bits of information that are related in some way or have some common characteristic or attribute.
Dimension	A measurable extent, such as the three principal dimensions of an object as in width, height, and depth.
Dimension Lines	A line which represents distance.
Dot Plot	See line plot.
Frequency	The rate at which something occurs over a particular period or in a given sample.
Graph	A diagram showing the relation between variable quantities, typically of two variables measured along a pair of lines at right angles.
Histogram	A graph of vertical bars representing the frequency distribution of a set of data.
International Organization for Standardization (ISO)	A non-governmental global organization whose principal activity is the development of technical standards through consensus.
International System of Units (SI)	An international system of units of measurement consisting of seven base units.
Line Plot	A method of visually displaying a distribution of data values where each data value is shown as a dot or mark above a number line. Also known as a dot plot.
Mean	A measure of center in a set of numerical data, computed by adding the values in a list and then dividing by the number of values in the list.
Measure	To determine the size, amount, or degree of an object by comparison with a standard unit.
Median	A measure of center in a set of numerical data. The median of a list of values is the value appearing at the center of a sorted version of the list – or the mean of the two central values if the list contains an even number of values.
Mode	The value that occurs most frequently in a given data set.

Normal Distribution	A function that represents the distribution of variables as a symmetrical bell-shaped graph.
Numeric Constraint	A number value or algebraic equation that is used to control the size or location of a geometric figure.
Precision	The degree to which repeated measurements show the same result.
Scale	1. A straight-edged strip of rigid material marked at regular intervals and used to measure distances. 2. A proportion between two sets of dimensions used in developing accurate, larger or smaller prototypes, or models of design ideas.
Scatter Plot	A graph in the coordinate plane representing a set of bivariate data.
Significant Digits	The digits in a decimal number that carry meaning contributing to the precision or accuracy of the quantity.
Standard Deviation	The distance of a value in a population (or sample) from the mean value of the population (or sample).
Statistics	Collection of methods for planning experiments, obtaining data, organizing, summarizing, presenting, analyzing, interpreting, and drawing conclusions based on data.
Unit	A standard quantity in terms of which other quantities may be expressed.
US Customary Measurement System	System of measurement used in the United States.
Variation	A change or slight difference in condition, amount, or level.

Unit 4 Key Terms

Key Term	Definition
Annotate	To add explanatory notes to a drawing.
Assembly	A group of machined or handmade parts that fit together to form a self-contained unit.
Assembly Drawing	A drawing that shows parts of an item when assembled.
Cartesian Coordinate System	A rectangular coordinate system created by three mutually perpendicular coordinate axes, commonly labeled X, Y, and Z.
Component	A part or element of a larger whole.
Computer-Aided Design or Computer-Aided Drafting (CAD)	1. When used in the context of design: the use of a computer to assist in the process of designing a part, circuit, building, etc. 2. When used in the context of drafting: the use of a computer to assist in the process of creating, storing, retrieving, modifying, plotting, and communicating a technical drawing.
Degree of Freedom	The variables by which an object can move. In assemblies, an object floating free in space with no constraints to another object can be moved along three axes of translation and around three axes of rotation. Such a body is said to have six degrees of freedom.
Design Brief	A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.
Design Statement	A part of a design brief that challenges the designer, describes what a design solution should do without describing how to solve the problem, and identifies the degree to which the solution must be executed.
Domain	The set of input values of a function.
Extrusion	1. A manufacturing process that forces material through a shaped opening. 2. A modeling process that creates a three-dimensional form by defining a closed two-dimensional shape and a length.
Function	1. A relationship from one set (called the domain) to another set (called the range) that assigns to each element of the domain exactly one element of the range. 2. The action or actions that an item is designed to perform.
Geometric Constraint	Constant, non-numerical relationships between the parts of a geometric figure. Examples include parallelism, perpendicularity, and concentricity.
Marketing	The promotion and selling of products or services.
Mathematical Modeling	The process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better, and to improve decisions.
Mock-up	A model or replica of a machine or structure for instructional or experimental purposes. Also referred to as an Appearance Model.

Model	A visual, mathematical, or three-dimensional representation in detail of an object or design, often smaller than the original.
Origin	A fixed point from which coordinates are measured.
Packaging	Materials used to wrap or protect goods.
Pattern	A repeated decorative design.
Physical Model	A physical representation of an object. Prototypes and appearance models are physical models.
Plane	A flat surface on which a straight line joining any two points would wholly lie.
Portfolio	A collection of documents selected for a particular purpose which may contain reflection on the contents of the documents or the related purpose. Varieties of portfolio types exist and are used for different purposes (e.g., project portfolio, course portfolio, longitudinal or growth portfolio, showcase portfolio).
Prototype	A full-scale working model used to test and improve a design concept by making actual observations and necessary adjustments.
Range	The set of output values of a function.
Revolution	Creating a 3D solid or surface by revolving a 2D shape about an axis.
Rotation	Turning around an axis or center point.
Round	A rounded exterior blend between two surfaces.
Scale Model	An enlarged or reduced representation of an object that is usually intended for study purposes.
Scoring	Making an impression or crease in a box blank to facilitate bending, folding, or tearing.
Solid	A three-dimensional body or geometric figure.
Solid Modeling	A type of 3D CAD modeling that represents the volume of an object, not just its lines and surfaces.
Subassembly	An assembled part that is a part of a larger assembly.
Translation	Motion in which all particles of a body move with the same velocity along parallel paths.
Working Drawings	Drawings that convey all of the information needed to manufacture and assemble a design.

Unit 5 Key Terms

Key Term	Definition
Acute Triangle	A triangle that contains only angles that are less than 90 degrees.
Angle	The amount of rotation needed to bring one line or plane into coincidence with another, generally measured in radians or degrees.
Area	The number of square units required to cover a surface.
Axis	1. An imaginary line through a body, about which it rotates. 2. An imaginary line about which a regular figure is symmetrically arranged. 3. A fixed reference line for the measurement of coordinates.
Center of Gravity	A 3D point where the total weight of the body may be considered to be concentrated.
Centroid	A 3D point defining the geometric center of a solid.
Circle	A round plane figure whose boundary consists of points equidistant from the center
Circumscribe	1. A triangle located round a polygon such as a circle. 2 To draw a figure around another, touching it at points but not cutting it.
Cylinder	A solid composed of two congruent circles in parallel planes, their interiors, and all the line segments parallel to the axis with endpoints on the two circles.
Density	The measure of mass density is a measure of mass per volume.
Diameter	A straight line passing from side to side through the center of a circle or sphere.
Ellipse	A shape generated by a point moving in a plane so that the sum of its distances from two other points (the foci) is constant and equal to the major axis
Fillet	A curve formed at the interior intersection between two or more surfaces.
Inscribe	To draw a figure within another so that their boundaries touch but do not intersect.
Mass	The amount of matter in an object or the quantity of the inertia of the object.
Meniscus	The curved upper surface of a liquid column that is concave when the containing walls are wetted by the liquid and convex when not.
Obtuse Triangle	A triangle with one angle that is greater than 90 degrees.
Parallelogram	A four-sided polygon with both pairs of opposite sides parallel.
Pi (π)	The numerical value of the ratio of the circumference of a circle to its diameter of approximately 3.14159.
Polygon	Any plane figure bounded by straight lines.
Principal Axes	The lines of intersection created from three mutually perpendicular planes, with the three planes' point of intersection at the centroid of the part.

Prism	A solid geometric figure whose two ends are similar, equal, and parallel rectilinear figures, and whose sides are parallelograms.
Quadrilateral	A four-sided polygon.
Radius	A straight line from the center to the circumference of a circle or sphere.
Rectangle	A parallelogram with 90 degree angles. A square is also a rectangle.
Regular Polygon	A polygon with equal angles and equal sides.
Right Triangle	A triangle that has a 90 degree angle.
Round	Two or more exterior surfaces rounded at their intersections.
Square	A regular polygon with four equal sides and four 90 degree angles.
Surface Area	The squared dimensions of the exterior surface
Tangent	A straight or curved line that intersects a circle or arc at one point only.
Title Block	A table located in the bottom right-hand corner of an engineering drawing that identifies, in an organized way, all of the necessary information that is not given on the drawing itself. Also referred to as a title strip.
Triangle	A polygon with three sides.
Vertex	Each angular point of a polygon, polyhedron, or other figure.
Volume	The amount of three-dimensional space occupied by an object or enclosed within a container.

Unit 6 Key Terms

Key Term	Definition
Aesthetic	1. Concerned with beauty or the appreciation of beauty. 2. Of pleasing appearance.
Asymmetry	Symmetry in which both halves of a composition are not identical. Also referred to as informal balance.
Balance	A condition in which different elements are equal or in the correct proportions. There are three types of visual balance: symmetry, asymmetry, and radial.
Color	The property possessed by an object of producing different sensations on the eye as a result of the way it reflects or emits light.
Contrast	The state of being noticeably different from something else when put or considered together.
Element	A basic constituent part.
Emphasis	Special importance, value, or prominence given to something.
Form	1. Having the three dimensions of length, width, and depth. Also referred to as a solid. 2. The organization, placement, or relationship of basic elements, as volumes or voids in a sculpture, so as to produce a coherent image.
Gestalt	The principle that maintains that the human eye sees objects in their entirety before perceiving their individual parts.
Graphic Design	The art of combining text and pictures in advertisements, magazines, books, etc.
Harmony	1. The quality of forming a pleasing and consistent whole. 2. Agreement or concord.
Message Analysis	The process of deciding what information needs to go into the graphic design, as well as how to effectively use the design elements and principles to present the information. This analysis is based on a thorough analysis of the audience.
Pattern	A repeated decorative design.
Pictograph	A pictorial symbol for a word or phrase.
Principle	The method of formation, operation, or procedure exhibited in a given instance.
Proportion	1. The relationship of one thing to another in size, amount, etc. 2. Size or weight relationships among structures or among elements in a single structure.
Radial Symmetry	Symmetry about a central axis.
Reverse	The process of taking something apart and analyzing its workings

Engineering	in detail.
Rhythm	A regularly recurring sequence of events or actions.
Shape	The two-dimensional contour that characterizes an object or area, in contrast to three-dimensional form.
Space	1. The dimensions of height, depth, and width within which all things exist and move. 2. A free or unoccupied area or expanse.
Symbol	A thing that represents or stands for something else, especially a material object representing something abstract.
Symbolism	1. The use of symbols to represent ideas or qualities. 2. The symbolic meaning attached to material objects.
Symmetry	The correspondence in size, shape, and relative position of parts on opposite sides of a median line or about a central axis. Also referred to as formal balance.
Texture	The feel, appearance, or consistency of a surface, substance, or fabric.
Typography	The style and appearance of printed matter.
Unity	The state of being united or forming a whole.
Value	The lightness or darkness of a color in relation to a scale ranging from white to black.
Variety	A thing which differs in some way from others of the same general class.

Unit 7 Key Terms

Key Term	Definition
Aligned Dimension	A system of dimensioning which requires all numerals, figures, and notes to be aligned with the dimension lines so that they may be read from the bottom (for horizontal dimensions) and from the right side (for vertical dimensions).
Allowance	The tightest possible fit between two mating parts.
American National Standards Institute (ANSI)	A private, non-profit organization that coordinates the development and use of a voluntary consensus standards in the United States.
American Society of Mechanical Engineers (ASME)	A professional engineering organization that is known for setting codes and standards for mechanical devices in the United States.
Audience Analysis	The understanding of the consumer group for which the design is targeted. This would include the audiences, demographics, physical location, amount of time available to view the design, and interest in the subject matter.
Auxiliary View	A view that is used to show features that are located on an inclined surface in true size and shape.
Baseline Dimensioning	System of dimensioning in which all dimensions are placed from a datum and not from feature to feature. Also referred to as Datum Dimensioning.
Balloon	A circle with a single number connected to an assembly component with a leader line to refer to parts.
Bilateral Tolerance	A tolerance in which variation is permitted in both directions from the specified dimension.
Blind Hole	A hole that does not go completely through the work piece.
Broken-Out Section	A section of an object broken away to reveal an interior feature for a sectional drawing.
Chain Dimensioning	Also known as point-to-point dimensioning where dimensions are established from one point to the next.
Clearance Fit	Limits the size of mating parts so that a clearance always results when mating parts are assembled.
Counterbore	A cylindrical recess around a hole, usually to receive a bolt head or nut.
Countersink	A conical-shaped recess around a hole, often used to receive a tapered screw.
Cutting Plane Line	A line drawn on a view where a cut was made in order to define the location of the imaginary section plane.
Datum	A theoretically exact point, axis, or plane derived from the true geometric counterpart of a specific datum feature. The origin from which the location, or geometric characteristic of a part feature, is

	established.
Datum Dimensioning	A dimensioning system where each dimension originates from a common surface, plane, or axis. Also known as baseline dimensioning.
Decision Matrix	A tool used to compare design solutions against one another, using specific criteria.
Detail Drawing	A dimensioned, working drawing of a single part. Also referred to as part drawing.
Detail View	A view that is used to show a magnified view of features that are too small to adequately specify in another view.
Dual Dimensions	Where alternate units are displayed within the same dimension.
Fillet	An inside radius between two intersecting planes.
Foreshorten	To show lines or objects shorter than their true size. Foreshortened lines are not perpendicular to the line of sight.
Full Section	A sectional drawing based on a cutting plane line that extends completely through an object.
Half Section	A sectional drawing based on a cutting plane line that cuts through one-quarter of an object. A half section reveals half of the interior and half of the exterior.
General Notes	Notes placed separate from the views; relate to the entire drawing.
Interference	The amount of overlap that one part has with another when assembled.
Interference Fit	Limits the size of mating parts so that an interference always results when mating parts are assembled.
International Organization for Standardization (IOS)	This is a worldwide organization that creates engineering standards.
Least Material Condition (LMC)	The smallest size limit of an external feature and the largest size limit of an internal feature.
Limit Dimensions	The largest and smallest possible boundaries to which a feature may be made as related to the tolerance of the dimension.
Local Notes	Connected to specific features on the views of the drawing. Also known as annotations.
Location Dimension	A location dimension that defines the relationship of features of an object.
Market Research	The activity of gathering information about consumers' needs and preferences.
Nominal Size	The designation of the size established for a commercial product.
Part Drawing	A drawing that contains all the information for making one part of the design.
Parts List	A list of materials or parts specified for a project. Also referred to as a bill of materials or BOM.
Pitch	A distance of uniform measure determined at a point on one unit to the same corresponding point on the next unit; used in threads,

	springs, and other machine parts.
Reference Dimension	A dimension, usually without a tolerance, used for information purposes only. A reference is a repeat of a given dimension or established from other values shown on a drawing. Reference dimensions are enclosed in ( ) on the drawing.
Round	An outside radius applied to corners.
Section Lines	Thin lines used in a section view to indicate where the cutting plane line has cut through material.
Section View	A view that is used to show details not apparent on the exterior of the part.
Size Dimension	Placed directly on a feature to identify a specific size or may be connected to a feature in the form of a note.
Specified Dimension	The dimension noted or, in the case of a tolerance, the part of the dimension from which the limits are calculated.
Spotface	A shallow recess like a counterbore, used to provide a good bearing surface for a fastener.
Survey	An investigation of the opinions or experience of a group of people, based on a series of questions.
Taper	Gradual diminution of width or thickness in an elongated object.
Technical Writing	A type of expository writing that is used to convey information for technical or business purposes.
Tolerance	The acceptable amount of dimensional variation that will still allow an object to function correctly..
Transition fit	Occurs when two mating parts can sometimes have a clearance fit and sometimes have an interference fit.
Unidirectional Dimension	A dimensioning system which requires all numerals, figures, and notes to be lettered horizontally and to be read from the bottom of the drawing sheet.
Unilateral Tolerance	A tolerance in which variation is permitted in only one direction from the specified dimension.
Working Drawings	Drawings that convey all of the information needed to manufacture and assemble a design.

Unit 8 Key Terms

Key Term	Definition
Exploded Assembly	An assembly drawing in which parts are moved out of position along an axis so that each individual part is visible.
Formula	A mathematical relationship or rule expressed in symbols.
Numeric Constraint	A number value or algebraic equation that is used to control the size or location of a geometric figure.
Parameter	A property of a system whose value determines how the system will behave.
Parametric Modeling	A CAD modeling method that uses parameters to define the size and geometry of features and to create relationships between features. Changing a parameter value updates all related features of the model at once.
Phantom Line	A line used to show the alternate positions of an object or matching part without interfering with the main drawing.
Ratio	The quantitative relation between two amounts showing the number of times one value contains or is contained within the other.
Rib	A relatively thin flat member acting as a brace support. Also called a web.

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Unit 9 Key Terms

Key Term	Definition
Arbitration	The hearing and determination of a dispute or the settling of differences between parties by a person or persons chosen or agreed to by them.
Attorney General	The principal legal officer of the Crown or a state.
By-product	Something produced in the making of something else; a secondary result; a side effect.
Carcinogen	A substance capable of causing cancer.
Consensus	General agreement.
Critique	A detailed analysis and assessment.
Ecosystem	A biological community of interacting organisms and their physical environment.
Environmental Protection Agency (EPA)	The US federal agency with a mission to protect human health and the environment.
Ergonomics	The study of workplace equipment design or how to arrange and design devices, machines, or workspace so that people and things interact safely and most efficiently.
Ethical	Conforming to an established set of principles or accepted professional standards of contact.
Ethics	The moral principles governing or influencing conduct.
Evaluate	To form an idea of the amount or value of; assess.
Gantt Chart	A time and activity bar chart that is used for planning, managing, and controlling major programs that have a distinct beginning and end.
Hazard	A danger or risk.
Impact	The effect or influence of one thing on another. Some impacts are anticipated, and others are unanticipated.
Landfill	A low area of land that is built up from deposits of solid refuse in layers covered by soil.
Mediation	The act or process of using an intermediary to effect an agreement or reconciliation.
Negotiation	Mutual discussion and arrangement of the terms of a transaction or agreement.

Norms	Principles of right action, binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior.
Occupation Safety and Health Administration (OSHA)	A government organization whose mission is to assure the safety and health of America's workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health.
Product Lifecycle	Stages a product goes through from concept and use to eventual withdrawal from the market place.
Protocol	The accepted code of behavior in a particular situation.
Raw Material	Any natural resource that is used to make finished products.
Recycle	To reclaim or reuse old materials in order to make new products.
Refurbish	To renovate or redecorate.
Refuse	Matter thrown away as worthless.
Residue	A small amount of something that remains after the main part has gone or been taken or used.
Synergy	When the unit or team becomes stronger than the sum of the individual members.
Trade-off	An exchange of one thing in return for another: especially relinquishment of one benefit or advantage for another regarded as more desirable.
Virtual Team	A group of people that rely primarily or exclusively on electronic forms of communication to work together in accomplishing goals.
Waste	Material which is eliminated or discarded as no longer useful or required.

Introduction to Engineering Design (IED)

Unit 1

Common Core State Standards for English Language Arts

AS.R.1 - Reading

Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

AS.R.7 - Reading

Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.R.10 - Reading

Read and comprehend complex literary and informational texts independently and proficiently.

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.5 - Writing

Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.7 - Writing

Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 - Writing

Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.SL.6 - Speaking and Listening

Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.1 - Writing

Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

9-10.W.1.a - Writing

Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among claim(s), counterclaims, reasons, and evidence.

9-10.W.1.b - Writing

Develop claim(s) and counterclaims fairly, supplying evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience's knowledge level and concerns.

9-10.W.1.c - Writing

Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

9-10.W.1.d - Writing

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.1.e - Writing

Provide a concluding statement or section that follows from and supports the argument presented.

9-10.W.2.a - Writing

Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.W.2.b - Writing

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.W.2.d - Writing

Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e - Writing

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.2.f - Writing

Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.5 - Writing

Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

9-10.W.7 - Writing

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.W.8 - Writing

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

9-10.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

9-10.SL.5 - Speaking and Listening

Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

9-10.SL.6 - Speaking and Listening

Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

9-10.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language

Spell correctly.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.RST.8 - Reading Science/Technical

Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem.

9-10.WHST.1 - Writing HS/S/T

Write arguments focused on discipline-specific content.

9-10.WHST.1.a - Writing HS/S/T

Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.

9-10.WHST.1.b - Writing HS/S/T

Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns.

9-10.WHST.1.c - Writing HS/S/T

Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

9-10.WHST.1.d - Writing HS/S/T

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.1.e - Writing HS/S/T

Provide a concluding statement or section that follows from or supports the argument presented.

9-10.WHST.2 - Writing HS/S/T

Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T

Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T

Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.2.f - Writing HS/S/T

Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.WHST.4 - Writing HS/S/T

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.5 - Writing HS/S/T

Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

9-10.WHST.7 - Writing HS/S/T

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.WHST.8 - Writing HS/S/T

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.WHST.9 - Writing HS/S/T

Draw evidence from informational texts to support analysis, reflection, and research.

9-10.WHST.10 - Writing HS/S/T

Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Introduction to Engineering Design (IED)

Unit 1

Next Generation Science Standards

Science and Engineering Practice - Engaging in Argument from Evidence

> Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

> Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

> Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

> Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Introduction to Engineering Design (IED)

Unit 1

Standards for Technological Literacy

1.9-12.L Students will develop an understanding of the characteristics and scope of technology.

> L. Inventions and innovations are the results of the specific, goal-directed research.

2.9-12.Z Students will develop an understanding of the core concepts of technology.

> Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

> AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.

> BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

4.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> I. Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

5.9-12.L Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.

8.9-12.H Students will develop an understanding of the attributes of design.

> H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

10.9-12.I Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

10.9-12.J Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

J. Technological problems must be researched before they can be solved.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 2

Common Core State Standards for English Language Arts

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

Introduction to Engineering Design (IED)

Unit 2

Common Core State Standards for Mathematics

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

Introduction to Engineering Design (IED)

Unit 2

Standards for Technological Literacy

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 3

Common Core State Standards for English Language Arts

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.RST.7 - Reading Science/Technical

Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

9-10.WHST.10 - Writing HS/S/T

Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Introduction to Engineering Design (IED)

Unit 3

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.CED.3 - Creating Equations

Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

S.ID.1 - Interpreting Categorical and Quantitative Data

Represent data with plots on the real number line (dot plots, histograms, and box plots).

S.ID.4 - Interpreting Categorical and Quantitative Data

Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

Introduction to Engineering Design (IED)

Unit 3

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology.

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

2.9-12.DD Students will develop an understanding of the core concepts of technology.

DD. Quality control is a planned process to ensure that a product, service, or system meets established criteria.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 4

Common Core State Standards for English Language Arts

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

9-10.W.2.a - Writing

Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.W.2.b - Writing

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.W.2.d - Writing

Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e - Writing

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.2.f - Writing

Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.5 - Speaking and Listening

Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

9-10.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language

Spell correctly.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.RST.7 - Reading Science/Technical

Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

9-10.WHST.2 - Writing HS/S/T

Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T

Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T

Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.2.f - Writing HS/S/T

Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.WHST.4 - Writing HS/S/T

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.10 - Writing HS/S/T

Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Introduction to Engineering Design (IED)

Unit 4

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions

Interpret parts of an expression, such as terms, factors, and coefficients.

A.CED.1 - Creating Equations

Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A.CED.2 - Creating Equations

Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A.CED.4 - Creating Equations

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

A.REI.3 - Reasoning with Equations and Inequalities

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A.REI.10 - Reasoning with Equations and Inequalities

Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

F.IF.1 - Interpreting Functions

Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, then f(x) denotes the output of f corresponding to the input x. the graph of f is the graph of the equation y = f(x).

F.IF.2 - Interpreting Functions

Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

F.IF.5 - Interpreting Functions

Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. For example, if the function h(n) gives the number of person-hours it takes to assemble n engines in a factory, then the positive integers would be an appropriate domain for the function.

F.IF.6 - Interpreting Functions

Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

F.IF.7.a - Interpreting Functions

Graph linear and quadratic functions and show intercepts, maxima, and minima.

F.BF.1 - Building Functions

Write a function that describes a relationship between two quantities.

F.LE.5 - Linear, Quadratic, and Exponential Models

Interpret the parameters in a linear or exponential function in terms of a context.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

S.ID.6 - Interpreting Categorical and Quantitative Data

Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

S.ID.6.a - Interpreting Categorical and Quantitative Data

Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.

S.ID.6.c - Interpreting Categorical and Quantitative Data

Fit a linear function for a scatter plot that suggests a linear association.

S.ID.7 - Interpreting Categorical and Quantitative Data

Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.

S.ID.8 - Interpreting Categorical and Quantitative Data

Compute (using technology) and interpret the correlation coefficient of a linear fit.

S.IC.1 - Making Inferences and Justifying Conclusions

Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

Introduction to Engineering Design (IED)

Unit 4

Next Generation Science Standards

HS.ETS1.2 - Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety , reliability , and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Developing and Using Models

Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.

Science and Engineering Practice - Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.

Science and Engineering Practice - Developing and Using Models

Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Science and Engineering Practice - Analyzing and Interpreting Data

Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Science and Engineering Practice - Analyzing and Interpreting Data

Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Science and Engineering Practice - Analyzing and Interpreting Data

Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Science and Engineering Practice - Analyzing and Interpreting Data

Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Science and Engineering Practice - Engaging in Argument from Evidence

Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.

Science and Engineering Practice - Engaging in Argument from Evidence

Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Introduction to Engineering Design (IED)

Unit 4

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology.

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 5

Common Core State Standards for English Language Arts

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.6 - Speaking and Listening

Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.SL.6 - Speaking and Listening

Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.3 - Reading Science/Technical

Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

Introduction to Engineering Design (IED)

Unit 5

Common Core State Standards for Mathematics

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.CED.4 - Creating Equations

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

A.REI.3 - Reasoning with Equations and Inequalities

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A.REI.4.b - Reasoning with Equations and Inequalities

Solve quadratic equations by inspection (e.g., for x2 = 49), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as a ± bi for real numbers a and b.

G.GMD.3 - Geometric Measurement and Dimension

Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

G.GMD.4 - Geometric Measurement and Dimension

Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.2 - Modeling with Geometry

Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Introduction to Engineering Design (IED)

Unit 5

Next Generation Science Standards

Crosscutting Concepts - Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Introduction to Engineering Design (IED)

Unit 5

Standards for Technological Literacy

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AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

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BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

8.9-12.H Students will develop an understanding of the attributes of design.

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L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 6

Common Core State Standards for English Language Arts

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.2.d - Writing

Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e - Writing

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

9-10.SL.5 - Speaking and Listening

Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

9-10.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language

Spell correctly.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.WHST.2 - Writing HS/S/T

Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T

Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T

Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.4 - Writing HS/S/T

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.10 - Writing HS/S/T

Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Introduction to Engineering Design (IED)

Unit 6

Next Generation Science Standards

Crosscutting Concepts - Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Crosscutting Concepts - Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Introduction to Engineering Design (IED)

Unit 6

Standards for Technological Literacy

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

> L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

> P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

> Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 7

Common Core State Standards for English Language Arts

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

9-10.W.2.a - Writing

Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.W.2.b - Writing

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.W.2.d - Writing

Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e - Writing

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language

Spell correctly.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.RST.7 - Reading Science/Technical

Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

9-10.WHST.2 - Writing HS/S/T

Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T

Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T

Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.4 - Writing HS/S/T

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.10 - Writing HS/S/T

Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Introduction to Engineering Design (IED)

Unit 7

Common Core State Standards for Mathematics

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

G.GMD.4 - Geometric Measurement and Dimension

Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Introduction to Engineering Design (IED)

Unit 7

Next Generation Science Standards

HS.ETS1.2 - Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Developing and Using Models

Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Science and Engineering Practice - Engaging in Argument from Evidence

Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Introduction to Engineering Design (IED)

Unit 7

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology.

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 8

Common Core State Standards for English Language Arts

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

Introduction to Engineering Design (IED)

Unit 8

Common Core State Standards for Mathematics

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.CED.1 - Creating Equations

Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A.CED.2 - Creating Equations

Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A.CED.3 - Creating Equations

Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A.REI.3 - Reasoning with Equations and Inequalities

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

F.LE.5 - Linear, Quadratic, and Exponential Models

Interpret the parameters in a linear or exponential function in terms of a context.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

Introduction to Engineering Design (IED)

Unit 8

Next Generation Science Standards

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Introduction to Engineering Design (IED)

Unit 8

Standards for Technological Literacy

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 9

Common Core State Standards for English Language Arts

AS.R.1 - Reading

Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

AS.R.7 - Reading

Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.R.10 - Reading

Read and comprehend complex literary and informational texts independently and proficiently.

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.7 - Writing

Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 - Writing

Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.SL.6 - Speaking and Listening

Adapt speech to a variety of contexts and communicative tasks, demonstrating command of formal English when indicated or appropriate.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

9-10.W.2.a - Writing

Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.W.2.b - Writing

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.W.2.d - Writing

Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e - Writing

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.2.f - Writing

Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.7 - Writing

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.W.8 - Writing

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

9-10.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.SL.1.b - Speaking and Listening

Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed.

9-10.SL.1.c - Speaking and Listening

Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

9-10.SL.1.d - Speaking and Listening

Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.

9-10.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

9-10.SL.5 - Speaking and Listening

Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

9-10.SL.6 - Speaking and Listening

Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

9-10.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language

Spell correctly.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.RST.4 - Reading Science/Technical

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

9-10.WHST.1 - Writing HS/S/T

Write arguments focused on discipline-specific content.

9-10.WHST.2 - Writing HS/S/T

Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T

Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T

Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.2.f - Writing HS/S/T

Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.WHST.4 - Writing HS/S/T

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.7 - Writing HS/S/T

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

9-10.WHST.8 - Writing HS/S/T

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

9-10.WHST.9 - Writing HS/S/T

Draw evidence from informational texts to support analysis, reflection, and research.

9-10.WHST.10 - Writing HS/S/T

Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Introduction to Engineering Design (IED)

Unit 9

Common Core State Standards for Mathematics

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Introduction to Engineering Design (IED)

Unit 9

Next Generation Science Standards

HS.ETS1.2 - Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety , reliability , and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

DCI - ESS3.A - Earth and Human Activity - Natural Resources

All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

DCI - ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosy stem degradation. (HS-ESS3-4)

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Asking questions and defining problems

Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.

Science and Engineering Practice - Developing and Using Models

Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Science and Engineering Practice - Engaging in Argument from Evidence

Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.

Science and Engineering Practice - Engaging in Argument from Evidence

Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Introduction to Engineering Design (IED)

Unit 9

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology.

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

4.9-12.H Students will develop an understanding of the cultural, social, economic, and political effects of technology.

H. Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious.

4.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

I. Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

4.9-12.J Students will develop an understanding of the cultural, social, economic, and political effects of technology.

J. Ethical considerations are important in the development, selection, and use of technologies.

5.9-12.L Students will develop an understanding of the cultural, social, economic, and political effects of technology.

L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

10.9-12.J Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

J. Technological problems must be researched before they can be solved.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

13.9-12.K Students will develop the abilities to assess the impact of products and systems.

K. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

17.9-12.Q Students will develop an understanding of and be able to select and use information and communication technologies.

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Introduction to Engineering Design (IED)

Unit 10

Common Core State Standards for English Language Arts

AS.R.7 - Reading

Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.8 - Writing

Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.1 - Speaking and Listening

Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

9-10.W.2.a - Writing

Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.W.2.b - Writing

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.W.2.d - Writing

Use precise language and domain-specific vocabulary to manage the complexity of the topic.

9-10.W.2.e - Writing

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.W.2.f - Writing

Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

9-10.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

9-10.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

9-10.SL.1 - Speaking and Listening

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

9-10.SL.5 - Speaking and Listening

Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

9-10.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

9-10.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

9-10.L.2.c - Language

Spell correctly.

9-10.L.6 - Language

Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

9-10.WHST.2 - Writing HS/S/T

Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

9-10.WHST.2.a - Writing HS/S/T

Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

9-10.WHST.2.b - Writing HS/S/T

Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

9-10.WHST.2.d - Writing HS/S/T

Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

9-10.WHST.2.e - Writing HS/S/T

Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

9-10.WHST.4 - Writing HS/S/T

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

9-10.WHST.10 - Writing HS/S/T

Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Introduction to Engineering Design (IED)

Unit 10

Common Core State Standards for Mathematics

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Introduction to Engineering Design (IED)

Unit 10

Next Generation Science Standards

HS.ETS1.2 - Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Developing and Using Models

Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Science and Engineering Practice - Engaging in Argument from Evidence

Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.

Science and Engineering Practice - Engaging in Argument from Evidence

Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Introduction to Engineering Design (IED)

Unit 10

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology.

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.BB Students will develop an understanding of the core concepts of technology.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

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SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Introduction to Engineering Design **GRADE: 9**

Unit	Standards	Unit Concept /Essential Ideas	Assessments
1: Design Process 2: Technical Sketching and Drawing 3: Measurement and Statistics 4: Modeling Skills 5: Geometry of Design 6: Reverse Engineering 7: Documentation 8: Advanced Computer Modeling 9: Design Team 10: Design Challenges	Standards for Technical Literacy and cross-curricular standards are outlined in detail in the Project Lead the Way Standards and Alignment for the Introduction to Engineering Design Course and is attached as a pdf document.	Key Concepts Concepts and Essential Ideas are outlined in detail in the Project Lead the Way Curriculum Framework for each unit and are attached as pdf documents. Content Specific Vocabulary Key Terms covered in each unit are provided by Project Lead the Way and attached as pdf documents.	Formative and summative assessments by lesson, unit, and course are outlined in detail in the Project Lead the Way Curriculum Framework for each unit and are attached as pdf documents.

TEACHER'S NAME: Timothy Elmer **6/17**

Curriculum Framework – Principles of Engineering (2015-2016)
Unit 1 Energy and Power – Lesson 1.1 Mechanisms

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Explore career opportunities in engineering and interview a professional engineer to gain insight related to pathway to engineering and current state of engineering.
• T2 – Apply the engineering design process to design a system using mechanisms to redirect energy within a system by manipulating force, speed, and distance.
• T3 – Determine the mechanical advantage of a simple machine or system of simple machines and characterize the work done by and power of a mechanical system.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – (Career Exploration) Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems.
• U2 – (Career Exploration) Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals.
• U3 – Most mechanisms are composed of gears, sprockets, pulley systems, and simple machines.
• U4 – Mechanisms are used to redirect energy within a system by manipulating force, speed, and distance.
• U5 – Mechanical advantage ratios relate input forces to output forces in mechanisms; efficiency ratios relate input work to output work for those mechanisms.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – What are some different types of occupations within the engineering pathway?
• Q2 – What are some common responsibilities of engineers?
• Q3 – Identify a mechanism in your household. Why do you think that particular mechanism is designed the way it is?
• Q4 - What are some strategies that can be used to make everyday mechanisms more efficient?
• Q5 - Describe one situation in which an engineer would want to include a mechanism with a mechanical advantage greater than one? What is the advantage in this case?
• Q6 - How could designing a solution to a mechanical problem without regard to efficiency be problematic?</td></tr>
</table>

Format guided by: Wiggins, G. & McTighe, J. (2011). The understanding by design guide to creating high quality units. Alexandria. VA: ASCD

<table>
<tr>
<td rowspan="3">
use the techniques, skills, and modern engineering tools necessary for engineering practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.
</td>
<td>
• U6 – (Design Process) Technical communication can be accomplished in oral, written, and visual forms and must be organized in a clear and concise manner.
• U7 – (Design Process) Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 in Lesson 1.4.)
</td>
<td></td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>
KNOWLEDGE: Students will…

• K1 – Describe the job responsibilities of various types of engineers and engineering technicians. U1, U2
• K2 – Know the six simple machines, their attributes, and components. U4
• K3 – Know the equations to solve for mechanical advantage, work, and power. U6
</td>
<td>
SKILLS: Students will…

• S1 – (Career Exploration) Differentiate among the various types of engineering careers and engineering technicians. U1, U2
• S2 – Measure forces and distances related to mechanisms. U4, U5
• S3 – Distinguish among the six simple machines, their attributes, and components. U4
• S4 – Calculate mechanical advantage and drive ratios of mechanisms. U4
• S5 – Design, create, and test systems using simple machines and drive mechanisms. U3, U4, U5, U6
• S6 – Calculate work and power in mechanical systems. U5, U6
• S7 – Determine efficiency in a mechanical system. U6
• S8 – Design, create, test, and evaluate a compound machine design. U3, U4, U5, U6
• S9 – (Design Process) Communicate a design for a machine using annotated sketches and other documentation. U3
• S10 – (Design Process) Collaborate effectively with others in a design team. U7
</td>
</tr>
</table>

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
1.1.0 Career Professional Interview	• 1.0.A.RU Professional Interview Rubric • Essential Questions	• 1.0.A.RU Professional Interview Rubric
1.1.1.A Simple Machines Investigation	• Essential Questions • Simple Machine Calculations • Student responses to presentation examples	• Conclusion Questions • Simple Machine Calculations
1.1.2.A Simple Machines Practice Problems	• Essential Questions	• Simple Machine Calculations
1.1.3.A.VEX Gears	• Essential Questions • Gear Calculations • Student responses to presentation examples	• Gear Calculations
1.1.4.A Pulleys, Drives, & Sprockets	• Essential Questions • A Pulleys, Drives, & Sprockets Calculations • Student responses to presentation examples	• Conclusion Questions • Pulley, Drives, & Sprockets Calculations
1.1.5.A Gears, Pulleys, Drives, & Sprockets Practice Problems	• Essential Questions	• Gear, Pulley, Drives, & Sprockets Calculations
1.1.6.P.VEX Compound Machine Design	• Essential Questions • 1.1.6.P.RU Compound Machine Design Rubric	• 1.1.6.P.RU Compound Machine Design Rubric

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
1.1.0 Career Professional Interview	K1, S1
1.1.1.A Simple Machines Investigation	S2, S3, S4, S5, S9, S10
1.1.2.A Simple Machines Practice Problems	S3,S4,S7
1.1.3.A.VEX Gears	S4, S5
1.1.4.A Pulleys, Drives, & Sprockets	S4
1.1.5.A Gears, Pulleys, Drives, & Sprockets Practice Problems	S3,S4
1.1.6.P.VEX Compound Machine Design	S3,S4, S5, S6, S7, S8, S9, S10

Format guided by: Wiggins, G. & McTighe, J. (2011). The understanding by design guide to creating high quality units. Alexandria. VA: ASCD

Curriculum Framework – Principles of Engineering (2015-2016)
Unit 1 Energy and Power – Lesson 1.2 Energy Sources

Desired Results *(stage 1)*

ESTABLISHED GOALS

It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability

Transfer

TRANSFER: Students will be able to independently use their learning to …

- T1 – Distinguish between nonrenewable, renewable, and inexhaustible energy sources and describe the process related in harnessing, storing, transporting, and converting energy.
- T2 – Design and characterize electrical circuits by calculating and describing the relationships between the current, voltage, and resistance in series circuits and parallel circuits.
- T3 – Identify the means of energy loss and calculate the efficiency of a system that converts electrical energy into mechanical energy.

Meaning

UNDERSTANDINGS: Students will understand that …

- U1 – Energy sources for consumption are varied, including nonrenewable, renewable, and inexhaustible sources.
- U2 – Energy sources for consumption are harnessed or mined, often stored and transported, and converted to other forms of energy.
- U3 – Energy often needs to be converted from one form to another to meet the needs of a given system.
- U4 – Energy can be transformed to do work.
- U5 – Efficiency describes how much energy or power is transformed in the manner desired.
- U6 – Power is the rate at which energy is transformed.
- U7 – The relationship among voltage, current, and resistance determines the behavior of electricity in a circuit.
- U8 – Electricity involves the motion of electrons and the electrical properties of a material (e.g., whether it is a

ESSENTIAL QUESTIONS: Students will keep considering …

- Q1 – Choose a specific energy production source. Explain why it is considered “clean.” In what ways may it not be so “clean?”
- Q2 – How might innovation of current technology involved with energy production provide energy more efficient?
- Q3 – What alternative energy source would be best implemented in your community? Explain why.
- Q4 – Choose a specific energy production source. What
- Q5 – What is one possible way that “lost” energy might be collected in your home or school and transformed for a useable purpose?
- Q6 – What are the advantages and disadvantages of wiring a house with either series or parallel circuits?

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to use the techniques, skills, and modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	conductor, an insulator, or a semiconductor) are determined by its atomic structure. • U9 – *(Design Process)* Effective presentations are the result of preparation, are tailored to suit the purpose and audience, and are improved by attending to posture, gestures, appearance, eye contact, and time constraints. (Same as U6 of Lesson 1.4.)	
	Acquisition	
	KNOWLEDGE: Students will… • K1 – Describe the characteristics of various sources of energy. U1, U2 • K2 – Know types of nonrenewable, renewable, and inexhaustible energy sources. U1, U2 • K3 – Know the equations for work and power. U4,U5,U6 • K4 – Know the equation for calculation the efficiency of a system. U5 • K5 – Know the equations related to describing the characteristics of simple circuits. U7	*SKILLS: Students will…* • S1 – *(Design Process)* Prepare and deliver a brief summary based on research. U9 • S2 – Calculate work and power. U3, U4, U5, U6 • S3 – Correctly use a digital multimeter as a voltmeter, ohmmeter, or ammeter. U7 • S4 – Calculate electrical power developed in a circuit. U6, U7 • S5 – Calculate mechanical power developed when lifting an object. U4, U6 • S6 – Determine efficiency of a system that converts an electrical energy to a mechanical energy. U3, U4, U5, U6, U7 • S7 – Calculate circuit resistance, current, and voltage using Ohm's law, including circuits with elements in series and/or parallel. U7 • S8 – Compare and contrast the behavior of electrical circuits with parallel and series circuit designs. U7

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A.1.2.1 Energy Sources	• 1.2.1.A.RU Energy sources Rubric • Essential Questions	• 1.2.1.A.RU Energy sources Rubric • Conclusion Questions
A.1.2.2 Energy Distribution	• Essential Questions	• Conclusion Questions
A.1.2.3 Electrical Circuits	• Essential Questions • Student responses to presentation examples.	• Demonstration of simulated circuits. • Demonstration of physical circuit. • Conclusion Questions
A.1.2.4 Circuit Calculations	• Essential Questions	• Calculations and Conclusion Questions
A.1.2.5 Mechanical System Efficiency	• Essential Questions • Student responses to presentation examples.	• Calculations and Conclusion Questions • Demonstration of mechanical system.

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A.1.2.1 Energy Sources	K1, S1
A.1.2.2 Energy Distribution	K1
A.1.2.3 Electrical Circuits	S3, S7
A.1.2.4 Circuit Calculations	S3, S7
A.1.2.5 Mechanical System Efficiency	S2, S3, S4, S5, S6

Curriculum Framework – Principles of Engineering (2015-2016)
Unit 1 Energy and Power– Lesson 1.3 Energy Applications

Desired Results *(stage 1)*

ESTABLISHED GOALS

It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.

Transfer

TRANSFER: Students will be able to independently use their learning to …

- T1 – Design a system to convert solar power to mechanical power using photovoltaic and fuel cells.
- T2 – Design, construct, and test insulation materials for reducing thermal energy transfer.
- T3 – Analyze system energy requirements to select the best energy sources for a system.
- T4 - Predict and manipulate the amount of heat energy transferred in a system resulting from the material properties and system design.

Meaning

UNDERSTANDINGS: Students will understand that …

- U1 – Selecting sources of energy for human consumption requires consideration of efficiency of energy transformations, of the quantities of energy needed and available, of the rates at which energy is needed and available, and of the accessibility of the power source to the point of consumption.
- U2 – Energy systems can include multiple energy sources that can be combined to convert energy into useful forms.
- U3 – Hydrogen fuel cells and solar cells are two of the many options for transforming energy to power human needs.
- U4 – The flow of heat energy in a system is related to material properties and system design, and by considering the thermodynamics of a system, an engineer can predict and manipulate the amount of energy transferred.
- U5 – *(Design Process)* Engineers use a design process to

ESSENTIAL QUESTIONS: Students will keep considering …

- Q1 – In what innovative ways could the efficiency of electricity production using solar cells be maximized throughout the day?
- Q2 – Describe how hydrogen fuel cells could become a viable way of producing energy for vehicles. What advancements in technology and infrastructure need to take place to make its usage more common?
- Q3 – A hydrogen fuel cell by itself is not sufficient to power much of anything in our society. How could fuel cells be configured to produce enough voltage and current to a system?
- Q4 – What are some materials in your home that provide prevent energy transfer from inside your home to the outside environment? Which of the three forms of energy transfer are they attempting to limit?
- Q5 – Which of the three forms of energy transfer are the

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<table>
<tr>
<td rowspan="3">

G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
G7 – Demonstrate an understanding of professional and ethical responsibility.
G8 – Demonstrate an ability to function on multidisciplinary teams.
G9 – Demonstrate an ability to communicate effectively.
G10 – Gain knowledge of contemporary issues.
G11 – Recognize the need for, and develop an ability to engage in life-long learning.

</td>
<td>
create solutions to existing problems. (Same as U2 of Lesson 1.4.)

U6 – (Design Process) Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 of Lesson 1.4.)

</td>
<td>materials in your home inhibiting the least? What could be done to change that?</td>
</tr>
<tr>
<th colspan="2">Acquisition</th>
</tr>
<tr>
<td>
KNOWLEDGE: Students will …

K1 – Explain that hydrogen fuel cells transform chemical energy stored in hydrogen gas to electrical energy and heat, converting hydrogen and oxygen into water. U1, U2, U3
K2 – Describe the use of reversible fuel cells as electrolyzers to store electrical energy for later use. U1, U2, U3
K3 – Describe the use of solar cells to convert light energy into electricity. U1, U2, U3
K4 – Describe convection, conduction, and radiation as they relate to thermal energy transfer. U4

</td>
<td>
SKILLS: Students will…

S1 – Test and apply the relationships among voltage, current, and resistance in series and parallel circuits that incorporate photovoltaic cells and hydrogen fuel cells. U1, U2, U3
S2 – Design a system to convert solar power to mechanical power using photovoltaic and fuel cells. U1, U3, U5, U6
S3 – Design, construct, and test insulation materials for reducing thermal energy transfer. U4
S4 – Calculate the rate at which energy is transferred by conduction and radiation through materials having various R-values. U4

</td>
</tr>
</table>

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A.1.3.1 Solar Hydrogen System	• Essential Questions • Calculations and measurements	• Conclusion Questions
P.1.3.2 Fuel Cell Technology		• Conclusion Questions • Presentation of designed solution
A.1.3.3 Thermodynamics	• Essential Questions • Student responses to presentation examples	• Conclusion Questions • Thermodynamic Calculations
P.1.3.4 Renewable Insulation	• 1.3.4.P.RU Renewable Insulation Rubric • Essential Questions	• 1.3.4.P.RU Renewable Insulation Rubric • Conclusion Questions • Thermodynamic Calculations

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A.1.3.1 Solar Hydrogen System	K1, K2, K3, S1, S2
P.1.3.2 Fuel Cell Technology	K1, K2, K3, S1, S2
A.1.3.3 Thermodynamics	K4, S4
P.1.3.4 Renewable Insulation	K4, S3, S4

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Curriculum Framework – Principles of Engineering (2015-2016)
Unit 1 Energy and Power – Lesson 1.4 Design Problem: Renewable Electrical Energy Design

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Apply an engineering design process to the creation of a renewable electrical energy design.
• T2 – To apply a decision matrix in a design process to best defend a selection or choice in a design process.
• T3 – To apply professional skills and work within a design team.
• T4 – Design and create a renewable electrical energy generating and distribution system that utilizes wind, solar electric, and fuel cell energy conversion systems as part of a team.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Design problems can be solved by individuals or in teams.
• U2 – Engineers use a design process to create solutions to existing problems.
• U3 – Design briefs are used to identify the problem specifications and to establish project constraints.
• U4 – Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships.
• U5 – Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions.
• U6 – Effective presentations are the result of preparation, are tailored to suit the purpose and audience, and are</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – How does a design team come to know what problem to solve?
• Q2 – Why is it important for the team to come to a consensus on issues that arise? What are some reasons why the team leader should not dictate the direction of the group?
• Q3 – What are two possible ways that a team could come to a consensus in a disagreement over a solution to a problem?
• Q4 – Engineers follow the design process, when solving a problem. What possible problems could arise, if the design process is not followed?</td></tr>
</table>

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• G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	improved by attending to posture, gestures, appearance, eye contact, and time constraints. **Acquisition** ***KNOWLEDGE:*** *Students will…* • K1 – Know the purpose of each part of a design brief. U3 • K2 – Describe a step-by-step, iterative design process. U2	 ***SKILLS:*** *Students will…* • S1 – Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U4, U5 • S2 – Create a decision making matrix for their design problem.U1, U2 • S3 – Select an approach that meets or satisfies the constraints provided in a design brief. U1, U3 • S4 – Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U1, U2, U4 • S5 – Present a workable solution to a design problem. U1, U2, U4, U6

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
B.1.4.1 Design Problem: Renewable Electrical Energy Design	• 1.4.1.P.RU Renewable Electrical Energy Design Rubric • Decision Matrix Rubric • Essential Questions	• 1.4.1.P.RU Renewable Electrical Energy Design Rubric • Decision Matrix Rubric • Conclusion Questions • Presentation of Design Process

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
B.1.4.1 Design Problem: Renewable Electrical Energy Design	K1, S1, S2, S3, S4, S5

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Curriculum Framework – Principles of Engineering (2015-2016)
Unit 2 Materials and Structures – Lesson 2.1 Statics

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Explore career opportunities in engineering and gain insight to current state of engineering.
• T2 – Characterize the forces acting on an object or system.
• T3 – Use vectors and moments to analyze forces acting on objects and design structural elements to transfer force effectively.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Laws of motion describe how forces affect a body.
• U2 – Applied forces are vector quantities with a defined magnitude, direction, and sense, and can be broken into vector components.
• U3 – Free body diagrams are used to illustrate and calculate forces acting upon a given body.
• U4 – Forces acting at a distance from an axis or point attempt or cause an object to rotate.
• U5 – Structural member properties – including centroid location, moment of inertia, and modulus of elasticity – are important considerations for structure design.
• U6 – Static equilibrium occurs when the sum of all forces acting on a body are equal to zero.
• U7 – Under static equilibrium conditions, the laws of motion can be used to calculate external forces on a truss and internal forces in truss members.
• U8 – (Design Process) Engineers and engineering</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – Why is it crucial for designers and engineers to construct accurate free body diagrams of the parts and structures that they design?
• Q2 – Why must designers and engineers calculate forces acting on bodies and structures?
• Q3 – When solving truss forces, why is it important to know that the structure is statically determinate?</td></tr>
</table>

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modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	technologists apply math, science, and discipline-specific skills to solve problems. (Same as U1 of Lesson 1.1.) • U9 – *(Career Exploration)* Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals. (Same as U2 of Lesson 1.1.)	
	Acquisition	
	KNOWLEDGE: Students will… • K1 – Differentiate between scalar and vector quantities. • K2 – Identify magnitude, direction, and sense of a vector. • K3 - Know beam deflection is related to cross sectional geometry and material properties. • K4 – Know the moment of inertia is related cross sectional geometry. • K5 – Know the modulus of elasticity defines the stiffness of an object related to material and chemical properties. • K6 – Know the forces acting on an object are in equilibrium. • K7 – Understand how Newton's Laws are applied to determine the forces acting on an object.	*SKILLS: Students will…* • S1 – Create free body diagrams of objects, identifying all forces acting on the object. U2, U3 • S2 – Mathematically locate the centroid of structural members. U4, U5 • S3 – Calculate the area moment of inertia of structural members. U5 • S4 – Calculate the deflection of a center-loaded beam from the beam's geometry and material properties. U5, U7 • S5 – Calculate the x- and y-components of a given vector. U2 • S6 – Calculate moments or torques given a force and a point of application relative to a specified axis. U4 • S7 – Use equations of equilibrium to calculate unknown external forces on a truss. U2, U3, U4, U6, U7 • S8 – Use the method of joints to calculate tension and compression forces in the members of a statically determinate truss. U2, U3, U6, U7 • S9 – Construct and destructively test a truss, and relate observations to calculated predications. U2, U3, U5, U6, U7

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A.2.1.0 Career Field Description	• 2.1.RU Career Field	• 2.1.RU Career Field

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A.2.1.0 Career Field Description	K1

	Description Rubric • Essential Questions	Description Rubric • Presentation of career field description
A.2.1.1 Centroids	• Essential Questions • Centroid calculations • Student responses to presentation examples	• Conclusion Questions
A.2.1.2 Beam Deflection	• Essential Questions • Centroid calculations • Student responses to presentation examples	• Conclusion Questions • Graph of deflection vs. moment
A.2.1.3 Free Body Diagrams	• Essential Questions • Student responses to presentation examples	• Conclusion Questions • Free body diagrams
A.2.1.4 Calculating Force Vectors	• Essential Questions • Force calculations • Student responses to presentation examples	• Calculations and Conclusion Questions
A.2.1.5 Calculating Moments	• Essential Questions • Moment calculations • Student responses to presentation examples	• Calculations and Conclusion Questions
A.2.1.6 Step-by-Step Truss Calculations	• Essential Questions • Truss calculations • Student responses to presentation examples	• Truss calculations
A.2.1.7 Calculating Truss Forces	• Essential Questions • Truss calculations • Student responses to presentation examples	• Truss calculations and Conclusion Questions

A.2.1.1 Centroids	S2
A.2.1.2 Beam Deflection	S3, S4
A.2.1.3 Free Body Diagrams	S1
A.2.1.4 Calculating Force Vectors	S1, S5
A.2.1.5 Calculating Moments	S5, S6
A.2.1.6 Step-by-Step Truss Calculations	S5, S6, S7, S8
A.2.1.7 Calculating Truss Forces	S5, S6, S7, S8

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A.2.1.8 Truss Design	• Essential Questions	• Conclusion Questions • Presentation of truss design and testing results

A.2.1.8 Truss Design	S5, S6, S7, S8, S9

Curriculum Framework – Principles of Engineering (2015-2016)
Unit 2 Energy and Power – Lesson 2.2 Material Properties

Desired Results *(stage 1)*

ESTABLISHED GOALS
It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability to use the techniques, skills, and

Transfer

TRANSFER: Students will be able to independently use their learning to…

- T1 – Describe the role and impact of engineering and engineering solutions within a global, economic, environmental, and societal context.
- T2 – Describe the properties of materials and calculate or identify through testing basic properties such as weight, volume, mass, density, surface area, and continuity, is the material ferrous metal, its hardness, and flexure.
- T3 – Select materials to meet design criteria based upon mechanical, thermal, electromagnetic, and chemical properties.
- T4 – Describe the importance of recycling and consideration of a products end of life while being designed.

Meaning

UNDERSTANDINGS: Students will understand that…

- U1 – Materials are the substances from which all things are made and are built from the elements.
- U2 – Materials can be categorized by their composition as pure elements, compounds, or mixtures, and are also typically classified as metallic, ceramic, organic, polymeric, or composite.
- U3 – Materials can be categorized by intrinsic physical and chemical properties, including mechanical, thermal, electromagnetic, and chemical properties.
- U4 – Material properties including recyclability and cost are important considerations for engineers when choosing appropriate materials for a design.
- U5 – Material selection is based upon mechanical, thermal, electromagnetic, and chemical properties.
- U6 – Raw materials undergo various manufacturing

ESSENTIAL QUESTIONS: Students will keep considering…

- Q1 – How does an engineer predict the performance and safety for a selected material?
- Q2 – What are the advantages and disadvantages of utilizing synthetic materials designed by engineers?
- Q3 – What ethical issues pertain to engineers designing synthetic materials?
- Q4 – What did you learn about the significance of selecting materials for product design?
- Q5 – How can an existing product be changed to incorporate different processes to make it less expensive and provide better performance?
- Q6 – How does an engineer decide which manufacturing process to use for a given material?
- Q7 – How do the recycling codes and symbols differ from state to state?

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modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	processes in the production of consumer goods. **Acquisition** *KNOWLEDGE: Students will…* • K1 – List material properties that are important too design including mechanical, chemical, electrical, and magnetic. • K2 – Know common manufacturing processes related to create a product from raw materials. • K3 - Know the steps of product life cycle for a common product.	 *SKILLS: Students will…* • S1 – Conduct non-destructive tests for material properties on selected common household products including tests for continuity, ferrous metal, hardness, and flexure. U2, U5 • S2 – Measure or calculate weight, volume, mass, density, and surface area of selected common household products. U3, U5 • S3 – Identify the manufacturing processes used to create the selected common household product. U6 • S4 – Identify materials that can be recycled. U4

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A.2.2.1 Product Analysis	• Essential Questions	• Product analysis document and conclusion questions
A.2.2.2 Manufacturing Processes	• Essential Questions • Student responses to presentation examples	• Conclusion questions
A.2.2.3 Recycling	• Essential Questions • Student responses to presentation examples	• Essential Questions • Recycling rubric

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A.2.2.1 Product Analysis	S1, S2, S3
A.2.2.2 Manufacturing Processes	S4
A.2.2.3 Recycling	K1, S5

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Curriculum Framework – Principles of Engineering (2015-2016)
Unit 2 Materials and Structures – Lesson 2.3 Material Testing

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Use a systematic process to solve problems.
• T2 – Interpreted and calculate material properties utilizing a stress strain curve for a tested sample.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Material testing helps determine a product's reliability, safety, and predictability in function.
• U2 – Engineers perform destructive and non-destructive tests on material specimens for the purpose of identifying and verifying the properties of various materials.
• U3 – Material testing, including tensile testing, is conducted under standardized conditions to provide a reproducible evaluation of material properties.
• U4 – Many properties related to a material's strength can be determined from a stress-strain curve for that material, including elastic range, proportional limit, modulus of elasticity, elastic limit, resilience, yield point, plastic deformation, ultimate strength, failure, and ductility
• U5 – Stress-strain data points are used to construct a stress-strain curve and to identify and calculate sample material properties.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – Why is it critical for engineers to document all calculation steps when solving problems?
• Q2 – How is material testing data useful?
• Q3 – Stress strain curve date points are useful in determining what specific material properties?</td></tr>
</table>

<table>
<tr>
<td rowspan="2">modern engineering tools necessary for engineering practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.</td>
<th colspan="2">Acquisition</th>
</tr>
<tr>
<td>KNOWLEDGE: Students will…

• K1 – Distinguish between stress and strain.
• K2 – Distinguish between elastic and plastic deformation. U4, U5
• K3 – Describe the relationship between the tensile force applied to a material and the elongation of the material as it deforms elastically, plastically, and then ruptures. U4, U5
• K4 – Define the modulus of elasticity.</td>
<td>SKILLS: Students will…

• S1 – Calculate minimum or maximum design parameters to ensure a safe or reliable product using material strength properties. U1, U4, U5
• S2 – Measure axial force and elongation data of material samples and create stress-strain diagrams describing the intrinsic properties of the materials. U2, U3
• S3 – Identify and calculate test sample material properties using a stress-strain curve. U1, U2, U3, U4, U5</td>
</tr>
</table>

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A.2.3.1 Stress/Strain Calculations	• Essential Questions • Student responses to presentation examples	• Calculations and Conclusion Questions
A.2.3.2 Tensile Testing	• Essential Questions	• Calculations and Conclusion Questions

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A.2.3.1 Stress/Strain Calculations	S1, S3
A.2.3.2 Tensile Testing	K1, K2, S2, S3

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Curriculum Framework – Principles of Engineering (2015-2016)
Unit 2 Lesson 2.4 Design Problem: Bridge Simulated Structural Design

Desired Results *(stage 1)*

ESTABLISHED GOALS
It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools

Transfer

TRANSFER: Students will be able to independently use their learning to …

- T1 – Apply an engineering design process to the creation of a simulated bridge design.
- T2 – To apply professional skills and work within a design team.
- T3 – Design and create the most efficient simulated bridge design based on specific design criteria.

Meaning

UNDERSTANDINGS: Students will understand that …

- U1 – Design problems can be solved by individuals or in teams.
- U2 – Engineers use a design process to create solutions to existing problems.
- U3 – Design briefs are used to identify the problem specifications and to establish project constraints.
- U4 – Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships.
- U5 – Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions.

ESSENTIAL QUESTIONS: Students will keep considering …

- Q1 – What is a design brief? What are design constraints?
- Q2 – Why is a design process so important to follow when creating a solution to a problem?
- Q3 – What is a decision matrix and why is it used?
- Q4 – What does consensus mean, and how do teams use consensus to make decisions?
- Q5 – How do the properties and types of materials affect the solution to a design problem?

necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	**Acquisition** *KNOWLEDGE: Students will …* • K1 – Know the purpose of each part of a design brief. U3 • K2 – Describe a step-by-step, iterative design process. U2	*SKILLS: Students will …* • S1 – Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U4, U5 • S2 – Create a decision-making matrix for a design problem. U1, U2 • S3 – Select an approach that meets or satisfies the constraints provided in a design brief. U1, U3 • S4 – Create a detailed pictorial sketch or use 3D-modeling software to document a proposed design. U1, U2, U4

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
B.2.4.1 Design Problem: Bridge Simulated Structural Design	• Essential Questions	• Conclusion Questions • Presentation of final simulated design

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
B.2.4.1 Design Problem: Bridge Simulated Structural Design	K1, S1, S2, S3, S4

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Curriculum Framework – Principles of Engineering (2015-2016)
Unit 3 Control Systems – Lesson 3.1 Machine Control

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – (Career Exploration) Explore career opportunities, salaries, and required education to engineering.
• T2 – Create control system operating programs that utilize computer software given needs and constraints.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Control systems are designed to provide consistent process control, reliability, and automation.
• U2 – Control system algorithms are a sequence of instructions, often involving conditional statements and iterative loops.
• U3 – Machines can use open-loop or closed-loop control systems; closed-loop control systems can use digital and/or analog sensor feedback to make decisions.
• U4 – Complex algorithms are created by decomposing the algorithm into simple pieces, and complex machine behavior can similarly be decomposed into simple component behavior.
• U5 – Documentation – in the form of pseudocode, comments, and other documentation – can be an important part of creating and maintaining a computer program.
• U6 – Version control can be an important part of creating</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – What are the advantages and disadvantages of using programmable logic to control machines versus monitoring and adjusting processes manually?
• Q2 – What are some everyday seemingly simple devices that contain microprocessors, and what function do the devices serve?
• Q3 – What questions must designers ask when solving problems in order to decide between digital or analog systems and between open or closed loop systems?</td></tr>
</table>

<table>
<tr>
<td rowspan="4">practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.</td>
<td>and maintaining a computer program.
• U7 – (Design Process) Design problems can be solved by individuals or in teams. (Same as U1 in Lesson 1.4)
• U8 – (Design Process) Engineers use a design process to create solutions to existing problems. (Same as U2 in Lesson 1.4)
• U9 – (Design Process) Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems. (Same as U1 of Lesson 1.1.)
• U10 – (Career Exploration) Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals. (Same as U2 of Lesson 1.1.)</td>
<td></td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>KNOWLEDGE: Students will …</td>
<td>SKILLS: Students will …</td>
</tr>
<tr>
<td>• K1 – Distinguish between digital and analog data, and between the inputs and outputs of a computational system. U3
• K2 – Distinguish open and closed loop systems based on whether decisions are made using time delays or sensor feedback. U3
• K3 – Identify the relative advantage of an open-loop or closed-loop control system for a given technological problem. U3
• K4 – (Career Exploration) Describe the market demand and salary range for one type of engineer or engineering technician, and understand the education path that leads to that career. U8, U9</td>
<td>• S1 – Choose appropriate input and output devices based on the need of a technological system. U1, U3
• S2 – Create a flow chart to describe an algorithm. U2, U5
• S3 – Create pseudocode to describe an algorithm. U2, U4, U5
• S4 – Analyze and describe an algorithm represented as a flowchart or as programming code. U2, U5
• S5 – Create a computer program to implement an algorithm, including conditional statements and iterations. U2, U3, U4, U5, U6
• S6 – Predict the behavior of a control system by examining the program it is going to execute. U2, U3, U4, U5
• S7 – Evaluate algebraic and logical expressions involving programming variables. U2, U5
• S8 – Use a variety of methods for finding, identifying, and correcting bugs in a program. U2, U3, U4, U5, U6
• S9 – Design and create a control system, including the</td>
</tr>
</table>

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		inputs, computer program, and outputs, based on given needs and constraints. U1, U2, U3, U4, U5, U6, U7, U8 • S10 – *(Design Process)* Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U3, U4, U7, U8 (Same as S1 of Lesson 1.4.) • S11 – *(Design Process)* Create a decision making matrix for a design problem. U7, U8 (Same as S1 of Lesson 1.4.) • S12 – *(Design Process)* Select an approach that meets or satisfies the constraints provided in a design brief. U1, U2, U3, U4, U7, U8 (Same as S1 of Lesson 1.4.) • S13 – *(Design Process)* Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U5, U7, U8 (Same as S1 of Lesson 1.4.) • S14 – *(Design Process)* Present a workable solution to a design problem. U1, U2, U4, U5, U7, U8 (Same as S1 of Lesson 1.4.)

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A3.1.0 Career, Demand, Salary, and Education	• 3.1.RU Career Demand, Salary, & Education Rubric • Essential Questions	• 3.1.RU Career Demand, Salary, & Education Rubric
A3.1.1 Inputs and Outputs	• Essential Questions • Instructor signoff of student demonstrated program	• Conclusion Questions
A3.1.2 Basic Outputs Programming	• Essential Questions	• Conclusion Questions • Print out of program
A3.1.3 Basic Inputs Programming	• Essential Questions	• Conclusion Questions • Print out of program
A3.1.4 While and If-else Structures	• Essential Questions	• Conclusion Questions • Print out of program
A3.1.5 Variables and Functions	• Essential Questions	• Conclusion Questions • Print out of program
A3.1.6 Open and Closed Loop Systems	• Essential Questions	• Conclusion Questions • Print out of program
P3.1.7 Machine Control Design	• 3.1.7.P.RU Machine Control Design Rubric (7 Problems) • Essential Questions	• 3.1.7.P.RU Machine Control Design Rubric (7 Problems) • Conclusion Questions

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A3.1.0 Career, Demand, Salary, and Education	K4
A3.1.1 Inputs and Outputs	K1, S1
A3.1.2 Basic Outputs Programming	K1, S1, S2, S3, S4
A3.1.3 Basic Inputs Programming	K1, S1, S2, S3, S4, S5
A3.1.4 While and If-else Structures	K1, S1, S2, S3, S4, S5, S6, S7, S8
A3.1.5 Variables and Functions	K1, S1, S2, S3, S4, S5, S6, S7, S8
A3.1.6 Open and Closed Loop Systems	K2, K3, S1, S2, S3, S4, S5, S6, S7
P3.1.7 Machine Control Design	K1, K2, K3, S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14

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		• Presentation of machine control design with program.		

Curriculum Framework – Principles of Engineering (2015-2016)
Unit 3 Control Systems – Lesson 3.2 Fluid Power

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.</td><th colspan="2">Transfer</th></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Design a system to solve a problem using hydraulic or pneumatics components.</td></tr>
<tr><th colspan="2">Meaning</th></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – The two types of fluid power systems – pneumatics and hydraulics – have both common and distinguishing characters.
• U2 – Fluid power is possible because in a system of confined fluid, pressure acts equally in all directions.
• U3 – All fluid power systems have basic components and functions in common, including a reservoir or receiver, a pump or compressor, a valve, and a cylinder.
• U4 – Fluid power systems are designed to transmit force over great distances, multiply an input force, and/or increase the distance that an output will move.
• U5 – Laws about the behavior of fluid systems and standard conventions for calculating values within fluid systems aid in the design and understanding of such systems.
• U6 – Standard schematic symbols and conventions are used to communicate fluid power designs.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – What impact does fluid power have on our everyday lives?
• Q2 – Can you identify devices or systems that do not use fluid power that might be improved with the use of fluid power?
• Q3 – What are similarities and differences of mechanical advantage in simple machines and hydraulic systems?
• Q4 – Why are Pascal’s Law, the perfect gas laws, Bernoulli’s Principle, and other similar rules important to engineers and designers of fluid power systems?</td></tr>
<tr><td></td><th colspan="2">Acquisition</th></tr>
</table>

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• G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	*KNOWLEDGE: Students will …* • K1 – Identify the advantages of hydraulic and pneumatic systems relative to each other. U1 • K2 – Identify and explain basic components and functions of fluid power devices. U3 • K3 – Distinguish between pressure and absolute pressure. U5 • K4 – Distinguish between temperature and absolute temperature. U5	*SKILLS: Students will …* • S1 – Identify devices that utilize hydraulic and pneumatic power. U1 • S2 – Distinguish between hydrodynamic and hydrostatic systems. U1 • S3 – Design, create, and test a hydraulic device. U1, U2, U3, U4, U5, U6 • S4 – Design, create, and test a pneumatic device. U1, U2, U3, U4, U5, U6 • S5 – Calculate design parameters in a fluid power system utilizing Pascal's Law. U2, U4, U5 • S6 – Calculate values in a pneumatic system utilizing the ideal gas laws. U2, U5 • S7 – Calculate flow rate, flow velocity, power, and mechanical advantage in a fluid power system. U5

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A3.2.1 Fluid Power Applications	• Essential Questions • Gear Calculations • Student responses to presentation examples	• Conclusion Questions • Student presentation
A3.2.2 Pneumatic Demonstration	• Essential Questions	• Conclusion Questions
A3.2.3 Fluid Power Practice Problems	• Essential Questions • Student responses to presentation examples	• Practice problems
P3.2.3 Pneumatic Brake Design (FT)	• 3.2.3.P.FT.RU Pneumatic Brake Design Rubric • Essential Questions	• 3.2.3.P.FT.RU Pneumatic Brake Design Rubric • Conclusion Questions • Presentation of final design
A3.2.4 Hydraulic Demonstration	• Essential Questions • Student responses to presentation examples	• Conclusion Questions
P3.2.5 Hydraulic Lift Design	• 3.2.5.P.FT.RU Hydraulic Lift Design Rubric • Essential Questions	• 3.2.5.P.FT.RU Hydraulic Lift Design Rubric • Conclusion Questions • Presentation of final design

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A3.2.1 Fluid Power Applications	K2, S1
A3.2.2 Pneumatic Demonstration	K2, S1
A3.2.3 Fluid Power Practice Problems	K3, K4, S5, S6, S7
P3.2.3 Pneumatic Brake Design (FT)	K2, S1, S2
A3.2.4 Hydraulic Demonstration	K1, K2, S1, S3
P3.2.5 Hydraulic Lift Design	K1, K2, S1, S4, S5

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Curriculum Framework – Principles of Engineering (2015-2016)
Unit 3 Control Systems – Lesson 3.3 Design Problem: Materials Sorter

Desired Results *(stage 1)*

ESTABLISHED GOALS

It is expected that students will…

- G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
- G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
- G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
- G5 – Demonstrate an ability to use the techniques, skills, and

Transfer

TRANSFER: Students will be able to independently use their learning to …

- T1 – Apply an engineering design process to the creation of a material sorter design.
- T2 – To apply a decision matrix in a design process to best defend a selection or choice in a design process.
- T3 – To apply professional skills and work within a design team.
- T4 – Design and create a renewable electrical energy generating and distribution system that utilizes wind, solar electric, and fuel cell energy conversion systems as part of a team.

Meaning

UNDERSTANDINGS: Students will understand that …

- U1 – Design problems can be solved by individuals or in teams. (Same as U1 of Lesson 1.4.)
- U2 – Engineers use a design process to create solutions to existing problems. (Same as U2 of Lesson 1.4.)
- U3 – Design briefs are used to identify the problem specifications and to establish project constraints. (Same as U3 of Lesson 1.4.)
- U4 – Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 of Lesson 1.4.)
- U5 – Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions. (Same as U5 of Lesson 1.4.)
- U6 – Effective presentations are the result of preparation,

ESSENTIAL QUESTIONS: Students will keep considering …

- Q1 – What is a design brief and what are design constraints?
- Q2 – Why is a design process so important to follow when creating a solution to a problem?
- Q3 – What is a decision matrix and why is it used?
- Q4 – What does consensus mean, and how do teams use consensus to make decisions?
- Q5 – How does the use of mechanisms affect the overall solution to a design problem?

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<table>
<tr>
<td rowspan="3">modern engineering tools necessary for engineering practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.</td>
<td>are tailored to suit the purpose and audience, and are improved by attending to posture, gestures, appearance, eye contact, and time constraints. (Same as U6 of Lesson 1.4.)</td>
<td></td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>KNOWLEDGE: Students will …

• K1 – Know the purpose of each part of a design brief. U3
• K2 – Describe a step-by-step, iterative design process. U2</td>
<td>SKILLS: Students will …

• S1 – Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U4, U5
• S2 – Create a decision making matrix for a design problem. U1, U2
• S3 – Select an approach that meets or satisfies the constraints provided in a design brief. U1, U3
• S4 – Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U1, U2, U4
• S5 – Present a workable solution to a design problem. U1, U2, U4, U6</td>
</tr>
</table>

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
B.3.3.1 Design Problem: Materials Sorter	• 3.3.1.P.RU Material Sorter Design Rubric • Essential Questions	• 3.3.1.P.RU Material Sorter Design Rubric • Conclusion Questions • Presentation of final design

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
B.3.3.1 Design Problem: Materials Sorter	S1, S2, S3, S4, S5

Curriculum Framework – Principles of Engineering (2015-2016)
Unit 4 Statistics and Kinematics – Lesson 4.1 Statistics

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and modern engineering tools</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">TRANSFERS: Students will be able to independently use their learning to …

• T1 – Analyze and interpret data in order to make valid and reliable claims or determine optimal design solutions.
• T2 – Determine the theoretical probability that an event will occur.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – Engineers use statistics to make informed decisions based upon established principles.
• U2 – Visual representations of data allow a person to understand and gain knowledge from the data.
• U3 – Descriptive statistics produce an abstraction from data, allowing us to communicate a meaningful summary instead of unenlightening details.
• U4 – The theoretical likelihood of an event can often be calculated based on a small number of simple assumptions.
• U5 – Inferential statistics allow us to generalize by drawing conclusions from data based on the laws of theoretical probability.
• U6 – (Design Process) Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems. (Same as U1 of Lesson 1.1.)
• U7 – (Career Exploration) Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals.</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – Why is it crucial for designers and engineers to utilize statistics throughout the design process?
• Q2 – Why is process control a necessary statistical process for ensuring product success?
• Q3 – Why is theory-based data interpretation valuable in decision making?
• Q4 – Why is experiment-based data interpretation valuable in decision making?</td></tr>
</table>

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<table>
<tr><td rowspan="3">necessary for engineering practice.
• G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• G7 – Demonstrate an understanding of professional and ethical responsibility.
• G8 – Demonstrate an ability to function on multidisciplinary teams.
• G9 – Demonstrate an ability to communicate effectively.
• G10 – Gain knowledge of contemporary issues.
• G11 – Recognize the need for, and develop an ability to engage in life-long learning.</td><td>(Same as U2 of Lesson 1.1.)</td><td></td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>KNOWLEDGE: Students will …

• K1 – Name measures of central tendency and variation and describe their meaning.
• K2 – Distinguish between sample statistics and population statistics and know appropriate applications of each.</td><td>SKILLS: Students will …

• S1 – (Career Exploration) Evaluate how personal career interests align or do not align with one or more fields of engineering or engineering technology. U6
• S2 – Calculate the theoretical probability that a simple event will occur. U4
• S3 – Produce a frequency distribution to describe experimental results and create a histogram to communicate these results. U2, U3
• S4 – Calculate the probability of making a set of observations in a series of trials where each trial has two distinct possible outcomes. U4
• S5 – Apply AND, OR, and NOT logic to probability. U4
• S6 – Apply Bayes' Theorem to calculate a probability in a manufacturing context. U4
• S7 – Calculate the central tendency of a data set, including mean, median, and mode.U3
• S8 – Calculate the variation in a set of data, including range, standard deviation, and variance. U3</td></tr>
</table>

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Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A4.1.0 Career Reflection, Abstract, Presentation	• 4.1.RU Career Reflection Abstract Presentation Rubric • Essential Questions	• 4.1.RU Career Reflection Abstract Presentation Rubric • Final student presentation
A4.1.1 Statistical Data Exploration	• Essential Questions • Student responses to presentation examples	• Histogram and Conclusion Questions
A4.1.2 Candy Statistics	• Essential Questions • Student responses to presentation examples	• Histogram and Conclusion Questions

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A4.1.0 Career Reflection, Abstract, Presentation	S1
A4.1.1 Statistical Data Exploration	S2, S3, S4, S5, S6, S7, S8
A4.1.2 Candy Statistics	S2, S3, S4, S5, S6, S7, S8

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Curriculum Framework – Principles of Engineering (2014-2015)
Unit 4 Statics and Kinematics – Lesson 4.2 Kinematics

<table>
<tr><th colspan="3">Desired Results (stage 1)</th></tr>
<tr><td rowspan="4">ESTABLISHED GOALS
It is expected that students will…

• G1 – Demonstrate an ability to identify, formulate, and solve engineering problems.
• G2 – Demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• G3 – Demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data.
• G4 – Demonstrate an ability to apply knowledge of mathematics, science, and engineering.
• G5 – Demonstrate an ability to use the techniques, skills, and</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">TRANSFER: Students will be able to independently use their learning to …

• T1 – Predict theoretically where a projectile should land based on the calculated initial velocity and the angle the projectile is fired at.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS: Students will understand that …

• U1 – When working with bodies in motion, engineers must be able to distinguish and calculate distance, displacement, speed, velocity, and acceleration.
• U2 – When air resistance is not taken into account, released objects will experience acceleration due to gravity, also known as freefall.
• U3 – Projectile motion can be predicted and controlled using kinematics equations.
• U4 – During projectile motion, velocity in the x-direction remains constant; while velocity in the y-direction changes at a constant rate due to gravity.
• U5 – (Design Process) Design problems can be solved by individuals or in teams. (Same as U1 of Lesson 1.4.)
• U6 – (Design Process) Engineers use a design process to create solutions to existing problems. (Same as U2 of Lesson 1.4.)
• U7 – (Design Process) Design briefs are used to identify the problem specifications and to establish project constraints. (Same as U3 of Lesson 1.4.)</td><td>ESSENTIAL QUESTIONS: Students will keep considering …

• Q1 – What are the relationships between distance, displacement, speed, velocity, and acceleration?
• Q2 – Why is it important to understand and be able to control the motion of a projectile?</td></tr>
</table>

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modern engineering tools necessary for engineering practice. • G6 – Pursue the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. • G7 – Demonstrate an understanding of professional and ethical responsibility. • G8 – Demonstrate an ability to function on multidisciplinary teams. • G9 – Demonstrate an ability to communicate effectively. • G10 – Gain knowledge of contemporary issues. • G11 – Recognize the need for, and develop an ability to engage in life-long learning.	• U8 – *(Design Process)* Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 of Lesson 1.4.) • U9 – *(Design Process)* Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions. (Same as U5 of Lesson 1.4.) • U10 – *(Design Process)* Effective presentations are the result of preparation, are tailored to suit the purpose and audience, and are improved by attending to posture, gestures, appearance, eye contact, and time constraints. (Same as U6 of Lesson 1.4.)	
	Acquisition	
	KNOWLEDGE: Students will … • K1 – Describe freefall motion of a projectile as having constant velocity in the horizontal direction and uniformly accelerating motion in the vertical direction. U4 • K2 – *(Design Process)* Know the purpose of each part of a design brief. U7 • K3 – *(Design Process)* Describe a step-by-step, iterative design process. U6	*SKILLS: Students will …* • S1 – Calculate distance, displacement, speed, velocity, and acceleration from data. U1, U2, U3, U4 • S2 – Design, build, and test a machine that efficiently channels mechanical energy when friction and limited input energy are significant constraints. U1 • S3 – Calculate acceleration due to gravity given data from a free-fall trajectory. U2, U4 • S4 – Calculate the x- and y-components of a projectile motion. U1, U3, U4 • S5 – Determine the angle needed to launch a projectile a specific range given the projectile's initial velocity. U1, U2, U3, U4 • S6 – *(Design Process)* Brainstorm and sketch possible solutions to an existing design problem. U5, U6, U8, U9 • S7 – *(Design Process)* Create a decision making matrix for a design problem. U5, U6 • S8 – *(Design Process)* Select an approach that meets or satisfies the constraints provided in a design brief. U5, U7 • S9 – *(Design Process)* Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U5, U6, U7

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		• S10 – *(Design Process)* Present a workable solution to a design problem. U5, U6, U8, U9

Evidence *(stage 2)*		
Activities (A) Projects (P) Problems(B)	Assessment FOR Learning	Assessment OF Learning
A4.2.1 Self Propelled Vehicle Design	• Essential Questions	• Conclusion Questions • Presentation of final design
A4.2.2 Projectile Motion	• Essential Questions • Student responses to presentation examples	• Calculations and Conclusion Questions
4.2.3 Design Problem: Ballistic Device		• Conclusion Questions • Presentation of final design

Learning Plan *(stage 3)*	
Activities (A) Projects (P) Problems(B)	Knowledge and Skills
A4.2.1 Self Propelled Vehicle Design	K1, S2, S4, S5, S6
A4.2.2 Projectile Motion	S3
4.2.3 Design Problem: Ballistic Device	K2, K3, S6,S7, S8,S9,S10

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Principles of Engineering **GRADE: 10**

Unit	Standards	Unit Concept /Essential Ideas	Assessments
1 Energy and Power 1.1 Mechanisms 1.2 Energy Source 1.3 Energy Applications 1.4 Renewable Energy 2 Materials and Structures 2.1 Statics 2.2 Material Properties 2.3 Material Testing 2.4 Structural Design 3 Control Systems 3.1 Machine Control 3.2 Fluid Power 3.3 Control	Standards for Technical Literacy and cross-curricular standards are outlined in detail in the Project Lead the Way Standards and Alignment for the Introduction to Engineering Design Course and is attached as a pdf document.	Key Concepts Concepts and Essential Ideas are outlined in detail in the Project Lead the Way Curriculum Framework for each unit and are attached as pdf documents. Content Specific Vocabulary Key Terms covered in each unit are provided by Project Lead the Way and attached as pdf documents.	Formative and summative assessments by lesson, unit, and course are outlined in detail in the Project Lead the Way Curriculum Framework for each unit and are attached as pdf documents.

TEACHER'S NAME: Timothy Elmer **6/17**

SUSSEX ACADEMY

CURRICULUM FRAMEWORK

COURSE: Principles of Engineering **GRADE: 10**

System 4 Statistics and Kinematics 4.1 Statistics 4.2 Kinematics			

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Lesson 1.1 Mechanisms – Key Terms

Term	Definition
ABET	The recognized accreditor for college and university programs in applied science, computing, engineering, and technology.
Actual Mechanical Advantage	The ratio of the magnitude of the resistance and effort forces applied to a system.
Belt	A continuous band of tough flexible material used to transmit motion and power within a pulley system.
Career	A profession for which one trains and which is undertaken as a long-term vocation.
Chain	A series of usually metal links or rings connected to or fitted into one another and used to transmit motion and power within a sprocket system.
Effort Force	An external force applied to an object.
Efficiency	The ratio of useful energy output to the total energy input, or the percentage of work input that is converted to work output.
Friction	The resistance that one surface or object encounters when moving over another.
Fulcrum	The fixed point around which a lever rotates.
Gear	A circular toothed object used to transfer rotary motion and torque through interlocking teeth.
Ideal Mechanical Advantage	Ratio of distance traveled by the applied effort and resistance force within a system.
Idler Gear	A gear positioned between the driver and the driven gear used to change rotational direction.
Inclined Plane	A flat surface set at an angle (or incline) with no moving parts that is able to lift objects by pushing or pulling the load.
Lever	A rigid bar used to exert a pressure or sustain a weight at one point of its length by the application of a force at a second point and turning at a third on a fulcrum.
Mechanism	The structure of or the relationship of the parts in a machine or in a construction or process comparable to a machine.
Moment	The turning effect of a force about a point equal to the magnitude of the force times the perpendicular distance from the point to the line of action from the force.
Pitch	Distance between adjacent threads in a screw.
Pulley	A type of lever that is a wheel with a groove in its rim, which is used to change the direction or multiply a force exerted by a rope or cable.
Resistance Force	Impeding effect exerted by one material object on another.

Screw	An inclined plane wrapped around a cylinder, forming the path and pitch.
Simple Machine	Any of various elementary mechanisms including the lever, wheel and axle, pulley, inclined plane, wedge, and screw.
Sprocket	A toothed wheel whose teeth engage the links of a chain.
Static Equilibrium	A condition where there are no net external forces acting upon a particle or rigid body and the body remains at rest or continues at a constant velocity.
Technical Communication	Creating, designing, and transmitting technical information so that people can understand it easily and use it safely, effectively, and efficiently.
Torque	A force that produces or tends to produce rotation or torsion.
Wedge	A substance that tapers to a thin edge and is used for splitting, raising heavy bodies, or tightening by being driven into something.
Wheel and Axle	Two differently sized circular objects that are attached together and turn as one.

Lesson 1.2 Energy Sources – Key Terms

Alternative Energy	Any source of energy other than fossil fuels that is used for constructive purposes.
Ampere	The unit of electric current in the meter-kilogram-second system of units. Referred to as amp and symbolized as A.
Biomass	Plant materials and animal waste used especially as a source of fuel.
Current	The net transfer of electric charge (electron movement along a path) per unit of time.
Electrical Energy	Energy caused by the movement of electrons.
Electricity	The flow of electrical power or charge.
Electromagnetic Induction	The production of electricity in conductors with the use of magnets.
Efficiency	The ratio of the useful energy delivered by a dynamic system to the energy supplied to it.
Energy	A fundamental entity of nature that is transferred between parts of a system in the production of physical change within the system and usually regarded as the capacity for doing work.
Energy Conversion	Changing one form of energy to another.
Environmental Protection Agency	An organization that works to develop and enforce regulations that implement environmental laws enacted by Congress.
Fossil Fuel	A natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.
Generator	A dynamo or similar machine for converting mechanical energy into electricity.
Geothermal Energy	The use of heat from within the Earth or from the atmosphere near oceans.
Gravitational Energy	The state when objects are not yet in motion.
Induction	The production of an electric or magnetic state by the proximity (without contact) of an electrified or magnetized body.
Inexhaustible Energy	An energy source that will never run out.
Kinetic Energy	Energy which a body possesses by virtue of being in motion.
Nonrenewable Energy	A resource that cannot be replaced once used.
Ohm	The unit of electric resistance in the meter-kilogram-second system of units. Symbolized as Ω.
Ohm’s Law	States that the direct current flowing in an electric circuit is directly proportional to the voltage applied to the circuit.
Parallel Circuit	A closed electrical circuit in which the current is divided into two or more paths and then returns via a common path to

	complete the circuit.
Potential Energy	The energy that a piece of matter has because of its position or nature or because of the arrangement of parts.
Power Converter	Changes one form of power to another.
Power Grid	A system that links electricity produced in power stations to deliver it to where it is needed.
Renewable Energy	A resource that can be replaced when needed.
Resistance	The opposition that a device or material offers to the flow of direct current.
Work	A result of a force moving an object a certain distance.
Turbine	A machine for producing power in which a wheel or rotor is made to revolve by a fast-moving flow of water, steam, gas, or air.
Power	The rate at which work is performed or energy is expended.
Rotor	The rotating member of an electrical machine.
Series Circuit	A circuit in which all parts are connected end to end to provide a single path of current.
Volt	The unit of potential difference symbolized as V.
Voltage	The potential difference measured in volts. The amount of work to be done to move a charge from one point to another along an electric circuit.

Lesson 1.3 Energy Applications – Key Terms

Active Solar Energy Collection	A type of system that uses circulating pumps and fans to collect and distribute heat.
Alternative Energy	Any source of energy other than fossil fuels that is used for constructive purposes.
Ampere	The unit of electric current in the meter-kilogram-second system of units. Referred to as amp and symbolized as A.
Conduction	The transfer of heat within an object or between objects by molecular activity, without any net external motion.
Convection	Process by which, in a fluid being heated, the warmer part of the mass will rise and the cooler portions will sink.
Current	The net transfer of electric charge (electron movement along a path) per unit of time.
Electrical Energy	Energy caused by the movement of electrons.
Electricity	The flow of electrical power or charge.
Electromagnetic Energy	Energy caused by the movement of light waves.
Electrolysis	The process separating the hydrogen-oxygen bond in water using an electrical current.
Energy	The ability to do work.
Entropy	The function of the state of a thermodynamic system whose change in any differential reversible process is equal to the heat absorbed by the system from its surroundings divided by the absolute temperature of the system.
First Law of Thermodynamics	The law that heat is a form of energy, and the total amount of energy of all kinds in an isolated system is constant; it is an application of the principle of conservation of energy. Also known as conservation of energy.
Fuel Cell Stack	Individual fuel cells that are combined in series.
Heat	Energy in transit due to a temperature difference between the source from which the energy is coming and a sink toward which the energy is going.
Kelvin	A unit of absolute temperature and symbolized as K. Formerly known as degree Kelvin.
Line of Best Fit	A straight line that best represents all data points of a scatter plot. This line may pass through some, all, or none of the points displayed by the scatter plot. Also referred to as a Trend Line or Regression Line.
Ohm	The unit of electric current in the meter-kilogram-second system of units. Symbolized as Ω.
Ohm's Law	States that the direct current flowing in an electric circuit is directly proportional to the voltage applied to the circuit.

Passive Solar Energy Collection	Systems that do not make use of any externally powered, moving parts, such as circulation pumps, to move heated water or air.
Product Development Life Cycle	Stages a product goes through from concept and use to eventual withdrawal from the market place.
Radiation	The process by which energy is transmitted through a medium, including empty space, as electromagnetic waves. This energy travels at the speed of light. This is also referred to as electromagnetic radiation.
Renewable Energy	A resource that can be replaced when needed.
Resistance	The opposition that a device or material offers to the flow of direct current.
R-value	The measure of resistance to heat flow.
Second Law of Thermodynamics	A general statement of the idea that there is a preferred direction for any process.
Temperature	A property of an object which determines the direction of heat flow when the object is placed in thermal contact with another object.
Thermal Equilibrium	Refers to the property of a thermodynamic system in which all parts of the system have attained a uniform temperature which is the same as that of the system's surroundings.
Thermodynamic System	A part of the physical world as described by its thermodynamic properties such as temperature, volume, pressure, concentration, surface tension, and viscosity.
Thermodynamics	The study of the effects of work, heat, and energy on a system.
U-value	A measure of thermal transmittance through a material.
Volt	The unit of potential difference symbolized as V.
Voltage	The potential difference measured in volts. The amount of work to be done to move a charge from one point to another along an electric circuit.
Zeroth Law of Thermodynamics	A law that if two systems are separately found to be in thermal equilibrium with a third system, the first two systems are in thermal equilibrium with each other; that is, all three systems are at the same temperature. Also known as thermodynamic equilibrium.

Lesson 1.4 Design Problem: Energy and Power – Key Terms

Accuracy	The condition or quality of being true, correct, or exact; precision; exactness.
Assembly	A group of machined or handmade parts that fit together to form a self-contained unit.
Brainstorming	A group technique for solving problems, generating ideas, stimulating creative thinking, etc., by unrestrained spontaneous participation in discussion.
Component	A part or element of a larger whole.
Consensus	A general agreement.
Constraint	A limit to a design process. Constraints may be such things as appearance, funding, space, materials, and human capabilities.
Decision Matrix	A tool for systematically ranking alternatives according to a set of criteria.
Design Brief	A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage consideration of all aspects of a problem before attempting a solution.
Design Modification	A major or minor change in the design of an item, effected in order to correct a deficiency, to facilitate production, or to improve operational effectiveness.
Design Process	A systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants and to winnow (narrow) down the possible solutions to one final choice.
Design Statement	A part of a design brief that challenges the designer, describes what a design solution should do without describing how to solve the problem, and identifies the degree to which the solution must be executed.
Designer	A person who designs any of a variety of things. This usually implies the task of creating drawings or in some way using visual cues to organize work.
Open-Ended	Not having fixed limits; unrestricted; broad.
Pictorial Sketch	A sketch that shows an object's height, width, and depth in a single view.
Problem Statement	A part of a design brief that clearly and concisely identifies a client's or target consumer's problem, need, or want.
Purpose	The reason for which something is done or for which something exists.
Sketch	A rough drawing representing the main features of an object or scene and often made as a preliminary study.
Solid Modeling	A type of 3D CAD modeling that represents the volume of an

	object, not just its lines and surfaces. This allows for analysis of the object's mass properties.
Target Consumer	A person or group for which product or service design efforts are intended.
Team	A collection of individuals, each with his or her own expertise, brought together to benefit a common goal.

Lesson 2.1 Statics – Key Terms

Cable	A strong rope, usually made of metal, designed to have great tensile strength and to be used in structures.
Centroid	The geometric center of an area.
Compression Force	A body subjected to a push.
Concurrent Force Systems	A force system where all of the forces are applied at a common point on the body or having their lines of action with a common intersection point.
Cross-Sectional Area	A surface or shape exposed by making a straight cut through something at right angles to the axis.
Direction	The direction of a vector is defined by the angle between a reference axis and the arrow's line of direction.
Fixed Support	A support that prevents translation and rotation in a beam.
Flange	A broad ridge or pair of ridges projecting at a right angle from the edge of a structural shape in order to strengthen or stiffen it.
Free Body Diagram	A diagram used to isolate a body from its environment, showing all external forces acting upon it.
Gusset	A plate or bracket for strengthening an angle in framework.
Joint	The connection points of members of a truss.
Magnitude	The absolute value of a number.
Member	Slender straight pieces of a truss connected by joints.
Method of Joints	A method of analysis of trusses which constructs free body diagrams of each joint and determines the forces acting in that joint by considering equilibrium of the joint pin.
Moment	The turning effect of a force about a point equal to the magnitude of the force times the perpendicular distance from the point to the line of action from the force.
Moment of Inertia	A mathematical property of a cross section that is concerned with a surface area and how that area is distributed about a centroidal axis.
Newton's First Law	Every body or particle continues at a state of rest or uniform motion in a straight line, unless it is compelled to change that state by forces acting upon it.
Newton's Second Law	The change of motion of the body is proportional to the net force imposed on the body and is in the direction of the net force.
Newton's Third Law	If one body exerts a force on a second body, then the second body exerts a force on the first body which is equal in magnitude, opposite in direction, and collinear.
Pinned Support	A support that prevents translation in any direction.
Planar Truss	A truss that lies in a single plane often used to support roofs and bridges.

Resultant Force	The resultant of a system of force is the vector sum of all forces.
Roller Support	A support that only prevents a beam from translating in one direction.
Scalar	A physical quantity that has magnitude only.
Sense	The sense of a vector is the direction of the vector relative to its path and indicated by the location of the arrow.
Simple Truss	A truss composed of triangles, which will retain its shape even when removed from supports.
Static Equilibrium	A condition where there are no net external forces acting upon a particle or rigid body and the body remains at rest or continues at a constant velocity.
Statically Indeterminate	A structure or body which is over-constrained such that there are more unknown supports than there are equations of static equilibrium.
Structure	Something made up of interdependent parts in a definite pattern of organization, such as trusses, frames, or machines.
Tension Force	A body subjected to a pull.
Vector Quantity	A quantity that has both a magnitude and direction.

Lesson 2.2 Material Properties – Key Terms

Additive Process	The process of creating an object by adding small pieces or layers together to make a final product.
Ceramic	Of or relating to the manufacture of any product (as earthenware, porcelain, or brick) made essentially from a nonmetallic mineral (as clay) by firing at a high temperature.
Codes	A systemized body of laws; a set of principles, as of ethics.
Composite	Solid material which is composed of two or more substances having different physical characteristics and in which each substance retains its identity while contributing desirable properties to the whole; especially, a structural material made of plastic within which a fibrous material (as silicon carbide) is embedded.
Decision Matrix	A tool for systematically ranking alternatives according to a set of criteria.
Finishing	Machining a surface to size with a fine feed produced in a lathe, milling machine, or grinder.
Forming	A process that changes the size and shape of a material by a combination of force and a shaped form.
Liability	Anything for which a person is legally bound or responsible.
Manufacturing	To make into a product suitable for use; to make from raw materials by hand or by machinery; to produce according to an organized plan and with division of labor.
Material	The elements, constituents, or substances of which something is composed or can be made; matter that has qualities which give it individuality and by which it may be categorized.
Mechanical Properties	Those properties of a material that reveal the elastic and inelastic reaction when force is applied, or that involve the relationship between stress and strain; for example, the modulus of elasticity, tensile strength, and fatigue limit.
Metals	Any of various opaque, fusible, ductile, and typically lustrous substances that are good conductors of electricity and heat.

Physical Properties	Properties other than mechanical properties that pertain to the physics of a material and can usually be measured without the application of force.
Polymers	Any of numerous natural and synthetic compounds of usually high molecular weight consisting of up to millions of repeated linked units, each a relatively light and simple molecule.
Product Life Cycle	Stages a product goes through from concept and use to eventual withdrawal from the marketplace.
Raw Material	Crude or processed material that can be converted by manufacture, processing, or combination into a new and useful product; something with a potential for improvement, development, or elaboration.
Recycling	Returning to an original condition. The extraction and recovery of valuable materials from scrap or other discarded materials.
Subtractive	Processes that remove material to change the size, shape, or surface of a part. There are two groups of separating processes: machining and shearing.
Synthetic	Produced by the combining of parts or elements to form a whole, rather than of natural origin; not real, artificial.

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Lesson 2.3 Material Testing – Key Terms

Axial Stress	A force with its resultant passing through the centroid of a particular section and being perpendicular to the plane of the section. A force in a direction parallel to the long axis of the structure.
Breaking Stress	The stress required to fracture a material whether by compression, tension, or shear.
Compression	When a material is reduced in volume by the application of pressure; the reciprocal of the bulk modulus.
Deformation	Any alteration of shape or dimensions of a body caused by stresses, thermal expansion or contraction, chemical or metallurgical transformations, or shrinkage and expansions due to moisture change.
Destructive Testing	Test methods used to examine an object, material, or system causing permanent damage to its usefulness.
Elastic Limit	Maximum stress that a material will withstand without permanent deformation.
Elongation	The fractional increase in a material's length due to stress in tension or thermal expansion.
Factor of Safety	The ratio of actual strength to required strength.
Failure Point	Condition caused by collapse, break, or bending, so that a structure or structural element can no longer fulfill its purpose.
Fatigue	The loss of the load-bearing ability of a material under repeated load application, as opposed to a single load.
Hooke's Law	The law stating that the stress of a solid is directly proportional to the strain applied to it.

Modulus of Elasticity	The ratio of the increment of some specified form of stress to the increment of some specified form of strain, such as Young's modulus, the bulk modulus, or the shear modulus. Also known as coefficient of elasticity, elasticity modulus, elastic modulus.
Nondestructive Testing	Test methods used to examine an object, material, or system without impairing its future usefulness.
Problem Solving	The ability to get answers to questions through a conscious, organized process. The answers are usually, but not necessarily, quantitative.
Proportional Limit	Point at which the deformation is no longer directly proportional to the applied force. Hooke's Law no longer applies.
Quality Control	Operational techniques necessary to satisfy all quality requirements; includes process monitoring and the elimination of root causes of unsatisfactory product or service quality performance.
Reliability	The probability that a component part, equipment, or system will satisfactorily perform its intended function under given circumstances, such as environmental conditions, limitations as to operating time, and frequency and thoroughness of maintenance for a specified period of time.
Resilience	A mechanical property of a material that shows how effectively the material is absorbing mechanical energy without sustaining any permanent damage.
Rupture Strength	Nominal stress developed in a material at rupture. Not necessarily equal to ultimate strength. Since necking is not taken into account in determining rupture strength, seldom indicates true stress at rupture.
Shear Stress	A measure of how easily a material can be twisted.
Standard Deviation	A statistical measurement of variability.
Statistics	The collection and analysis of numerical data in large quantities.
Strain	Change in the length of an object in some direction per unit.

Stress	The force acting across a unit area in a solid material resisting the separation, compacting, or sliding that tends to be induced by external forces.
Stress-Strain Curve	Graphical representation of a material's mechanical properties.
Tension	The condition of a string, wire, or rod that is stretched between two points.
Toughness	Mechanical property of a material that indicates the ability of the material to handle overloading before it fractures.
Ultimate Stress	Sometimes referred to as tensile strength; determined by measuring the maximum load a material specimen can carry when in the shape of a rectangular bar or cylindrical can.
Variance	The average of the squared differences from the mean.

Lesson 2.4 Key Terms

Key Terms

Term	Definition
Accuracy	1. The condition or quality of being true, correct, or exact; precision; exactness. 2. The degree of correctness of a quantity or expression.
Assembly	A group of machined or handmade parts that fit together to form a self-contained unit.
Brainstorming	A group technique for solving problems, generating ideas, stimulating creative thinking, etc., by unrestrained spontaneous participation in discussion.
Component	A part or element of a larger whole.
Consensus	A general agreement.
Constraint	1. A limit to a design process. Constraints may be such things as appearance, funding, space, materials, and human capabilities. 2. A limitation or restriction.
Decision Matrix	A tool for systematically ranking alternatives according to a set of criteria.
Design Brief	A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.
Design Modification	A major or minor change in the design of an item, effected in order to correct a deficiency, to facilitate production, or to improve operational effectiveness.
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Designer	A person who designs any of a variety of things. This usually implies the task of creating drawings or in some way using visual cues to organize work.
Open-Ended	Not having fixed limits; unrestricted; broad.
Pictorial Sketch	A sketch that shows an object's height, width, and depth in a single view.
Problem Statement	A part of a design brief that clearly and concisely identifies a client's or target consumer's problem, need, or want.
Purpose	The reason for which something is done or for which something exists.

Sketch	A rough drawing representing the main features of an object or scene and often made as a preliminary study.
Solid Modeling	A type of 3D CAD modeling that represents the volume of an object, not just its lines and surfaces. This allows for analysis of the object's mass properties.
Target Consumer	A person or group for which product or service design efforts are intended.
Team	A collection of individuals, each with his or her own expertise, brought together to benefit a common goal.

Lesson 3.1 Machine Control – Key Terms

Algorithm	A step-by-step procedure for solving a problem or accomplishing some end, especially by a computer.
Analog Signal	A signal having the characteristic of being continuous and changing smoothly over a given range, rather than switching suddenly between certain levels.
Analog to Digital	Conversion of an analog signal to a digital quantity such as binary.
Closed Loop System	A control system that considers the output of a system and makes adjustments based on that output.
Data	Information encoded in a digital form, which is usually stored in an assigned address of a data memory for later use by the processor.
Digital Signal	A system of discrete states: high or low, on or off, 1 or 0.
Digital to Analog	Conversion of a digital signal to its analog equivalent, such as a voltage.
Electromagnet	A conductor wrapped around an iron core. The two ends of the conductor are attached to a power source. When current passes through the conductor, the iron core becomes magnetized.
Feedback	The return to the input of a part of the output of a machine, system, or process (as for producing changes in an electronic circuit that improve performance or in an automatic control device that provide self-corrective action).
Flowchart	A diagram that shows step-by-step progression through a procedure or system especially using connecting lines and a set of conventional symbols.
Input	Information fed into a data processing system or computer.
Interface	The place at which independent and often unrelated systems meet and act on or communicate with each other.
Microprocessor	The central processing unit that is generally made from a single integrated circuit.
Normally Closed	The contact of a relay that is closed when the coil is de-energized.
Normally Open	The contact of a relay that is open when the coil is de-energized.
NTC Resistor	A negative temperature coefficient, also known as a thermistor, is a sensitive resistor whose primary function is to exhibit a change in electric resistance with a change in temperature.
Open Loop System	A control circuit in which the system output has no effect on the control.
Output	The information produced by a computer.

Photocell	A photo-sensitive resistor whose resistance decreases as the light striking the unit increases.
Polarity	The type of charge an atomic particle has.
Potentiometer	A switch that can provide variable motion control. It can vary the resistance within the switch, which affects both the current and voltage flowing out of the switch.
Programmable Logic Controller	A specialized heavy-duty computer system used for process control in factories, chemical plants, and warehouses. Closely associated with traditional relay logic. Also called a programmable controller (PC).
Reed Switch	An electromagnetically operated switching device.
Sensor	A device that responds to a physical stimulus (as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control).
Subroutine	A subordinate routine; specifically, a sequence of computer instructions for performing a specified task that can be used repeatedly.
Switch	A device for making, breaking, or changing the connections in an electrical circuit.
Transistor	A solid-state switching device.

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Lesson 3.2 Fluid Power – Key Terms

Absolute Pressure	The total pressure exerted on a system, including atmospheric pressure.
Atmospheric Pressure	The pressure exerted by the weight of the atmosphere above the point of measurement.
Boyle's Law	The volume of a gas at constant temperature varies inversely with the pressure exerted on it.
Charles' Law	States that the volume of a confined gas is proportional to its temperature, provided its pressure remains constant.
Check Valve	A valve that allows flow in one direction but prevents flow in the opposite direction.
Compressor	An air pump that compresses air into a receiver tank.
Crank	A part of an axle or shaft bent out at right angles, for converting reciprocal to circular motion and vice versa.
Cylinder	A device used to convert fluid power into mechanical power in the form of linear motion.
Directional-Control Valve	Used to control which path fluid takes in a circuit.
Double-Acting Cylinder	A cylinder that can act under pressure in both directions (extend and retract) to move a load.
Filter	A device used to remove contamination from a fluid.
Flow Meter	A device used to measure flow rate.
Flow Rate	The volume of fluid that moves through a system in a given period of time.
Flow Velocity	The distance the fluid travels through a system in a given period of time.
Flow-Control Valve	Used to start and stop flow in a circuit.
Fluid Power	The use of a fluid (liquid or gas) to transmit power from one location to another.
Gay-Lussac's Law	The absolute pressure of a confined gas is proportional to its temperature, provided its volume stays constant.
Hydraulics	The use of a liquid flowing under pressure to transmit power from one location to another.
Lubricator	A device used to spray an oil mist into the stream of a pneumatic system.
Pascal's Law	Pressure exerted by a confined fluid acts undiminished equally in all directions.
Piston	A sliding piece moved by or moving against fluid pressure which usually consists of a short cylindrical body fitting within a cylindrical chamber or vessel along which it moves back and forth.
Pneumatics	The use of gas flowing under pressure to transmit power from

	one location to another.
Pressure	The force per unit area exerted by a fluid against a surface.
Pressure Regulator	A type of pneumatic pressure control valve that controls the maximum pressure in a branch of a circuit.
Pressure Relief Valve	A type of pressure control valve that limits the maximum pressure in a hydraulic or pneumatic circuit.
Pump	A device used to create flow in a hydraulic system.
Receiver Tank	A device that holds the compressed air in a pneumatic system.
Reservoir	The tank that holds the fluid in a hydraulic system.
Single-Acting Cylinder	A cylinder that acts under pressure in one direction only and returns automatically when the pressure is released.
Solenoid	A switching device that uses the magnetic field generated by an electrical current for actuation.
Transmission Lines	Used to transport fluid in a circuit.
Valve	Any device that controls, either automatically or manually, the flow of a fluid.
Viscosity	A measure of a fluid's thickness or resistance to flow.
Volume	The amount or quantity of something.

Lesson 3.3 Design Problem: Control Systems – Key Terms

Accuracy	The condition or quality of being true, correct, or exact; precision; exactness.
Assembly	A group of machined or handmade parts that fit together to form a self-contained unit.
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Purpose	The reason for which something is done or for which something exists.
Sketch	A rough drawing representing the main features of an object or scene and often made as a preliminary study.

Solid Modeling	A type of 3D CAD modeling that represents the volume of an object, not just its lines and surfaces. This allows for analysis of the object's mass properties.
Target Consumer	A person or group for which product or service design efforts are intended.
Team	A collection of individuals, each with his or her own expertise, brought together to benefit a common goal.

PLTW Engineering

Lesson 4.1 Statistics – Key Terms

Accuracy	Degree of conformity of a measure to a standard value.
Bar Chart	Categorical data graph.
Bayes' Theorem	The probability of an event occurring based upon other event probabilities.
Data	Numbers or information describing some characteristic.
Data Variation	Measure of data scatter.
Deviation	Amount of difference between a value and the mean.
Experiment	An activity with observable results.
Event	A subset of a sample space.
Frequency Distribution	Listing of data values along with their corresponding frequencies.
Frequency Polygons	Frequency distribution graph.
Histogram	Frequency distribution graph.
Mean	Arithmetic average.
Mean Deviation	Measure of variation equal to the sum of the deviations of each value from the mean.
Median	Middle value of a set of values arranged in order of magnitude.
Mode	The value that occurs most frequently.
Normal Distribution	Bell-shaped probability distribution.
Outcome	The result of an experiment.
Pie Chart	Categorical data graph to illustrate percentage.
Probability	The calculated likelihood that a given event will occur.
Process Control	To monitor and control a process so that the quality of the output/product improves.
Qualitative Data	Values that possess names or labels.
Quantitative Data	Values that represent a measurable quantity.
Quality Assurance	The use of quality control techniques associated with a process.
Reliability	The probability of satisfactory operation of the product in a given environment over a specified time interval.
Sample Space	A set of all possible outcomes or events in an experiment that cannot be further broken down.
Standard Deviation	The square root of the variance.
Statistics	The collection, evaluation, and interpretation of data.
Statistical Process Control	SPC is a method of monitoring, controlling, and ideally improving a process through statistical analysis. Its four basic steps include measuring the process, eliminating variances in the process to make it consistent, monitoring the process, and improving the process to its best target value.
Tolerance	The difference between the maximum and minimum dimensions allowed within the design of a product.
Variance	The difference between samples.

Lesson 4.2 Kinematics – Key Terms

Free Fall	The condition of unrestrained motion in a gravitational field.
Distance	The total length of the path over which the particle travels.
Displacement	A vector quantity giving the straight-line distance and direction from an initial position to a final position.
Velocity	A vector quantity that includes the speed and direction of an object.
Speed	The magnitude of the total distance traveled divided by the time elapsed.
Acceleration	The rate of change of velocity with respect to time.

Principles of Engineering (PoE)

Lesson 1.1

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions

Interpret parts of an expression, such as terms, factors, and coefficients.

A.SSE.1.b - Seeing Structure in Expressions

Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

A.CED.1 - Creating Equations

Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A.CED.4 - Creating Equations

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

A.REI.3 - Reasoning with Equations and Inequalities

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

F.LE.1.b - Linear, Quadratic, and Exponential Models

Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Principles of Engineering (PoE)

Lesson 1.1

Next Generation Science Standards

DCI - PS3.A - Energy - Definitions of Energy

At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Conserv ation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

The availability of energy limits what can occur in any system. (HS-PS3-1)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

Science and Engineering Practice - Analyzing and Interpreting Data

Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

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Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Changes in systems may have various causes that may not have equal effects.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

The total amount of energy and matter in closed systems is conserved.

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Principles of Engineering (PoE)

Lesson 1.1

Standards for Technological Literacy

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 1.2

Next Generation Science Standards

HS.PS3.3 - Energy

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS.PS3.4 - Energy

Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

HS.ESS3.1 - Earth and Human Activity

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS.ESS3.2 - Earth and Human Activity

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.1 - Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

DCI - PS3.A - Energy - Definitions of Energy

“Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5)

DCI - PS3.A - Energy - Definitions of Energy

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2)

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DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

The availability of energy limits what can occur in any system. (HS-PS3-1)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary to HS-PS4-5)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering.

These global challenges also may have manifestations in local communities. (HS-ETS1-1)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

DCI - ESS3.A - Earth and Human Activity - Natural Resources

Resource availability has guided the development of human society. (HS-ESS3-1)

DCI - ESS3.A - Earth and Human Activity - Natural Resources

All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

DCI - ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosy stem degradation. (HS-ESS3-4)

DCI - ESS3.D - Earth and Human Activity - Global Climate Change

Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

Science and Engineering Practice - Developing and Using Models

Design a test of a model to ascertain its reliability.

Science and Engineering Practice - Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.

Science and Engineering Practice - Developing and Using Models

Develop a complex model that allows for manipulation and testing of a proposed process or system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.

Science and Engineering Practice - Planning and Carrying Out Investigations

Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

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Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Changes in systems may have various causes that may not have equal effects.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

The total amount of energy and matter in closed systems is conserved.

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Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Energy drives the cycling of matter within and between systems.

Crosscutting Concepts - Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Principles of Engineering (PoE)

Lesson 1.2

Standards for Technological Literacy

4.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> I. Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

4.9-12.J Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> J. Ethical considerations are important in the development, selection, and use of technologies.

4.9-12.K Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> K. The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.

5.9-12.G Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> G. Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.

5.9-12.H Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> H. When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.

5.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> I. With the aid of technology, various aspects of the environment can be monitored to provide information for decision-making.

5.9-12.J Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> J. The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.

5.9-12.K Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> K. Humans devise technologies to reduce the negative consequences of other technologies.

5.9-12.L Students will develop an understanding of the cultural, social, economic, and political effects of technology.

L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.J Students will develop an understanding of and be able to select and use energy and power technologies.

J. Energy cannot be created nor destroyed; however, it can be converted from one form to another.

16.9-12.K Students will develop an understanding of and be able to select and use energy and power technologies.

K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.M Students will develop an understanding of and be able to select and use energy and power technologies.

M. Energy resources can be renewable or nonrenewable.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 1.3

Next Generation Science Standards

HS.PS3.3 - Energy

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS.PS3.4 - Energy

Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

HS.ESS3.1 - Earth and Human Activity

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS.ESS3.2 - Earth and Human Activity

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.1 - Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

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"Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5)

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Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2)

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DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering.

These global challenges also may have manifestations in local communities. (HS-ETS1-1)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety , reliability , and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

DCI - ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

DCI - ESS3.D - Earth and Human Activity - Global Climate Change

Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

Science and Engineering Practice - Developing and Using Models

Develop a complex model that allows for manipulation and testing of a proposed process or system.

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Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

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Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Changes in systems may have various causes that may not have equal effects.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

The total amount of energy and matter in closed systems is conserved.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Principles of Engineering (PoE)

Lesson 1.3

Standards for Technological Literacy

4.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> I. Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

4.9-12.J Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> J. Ethical considerations are important in the development, selection, and use of technologies.

4.9-12.K Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> K. The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.

5.9-12.G Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> G. Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.

5.9-12.H Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> H. When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.

5.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> I. With the aid of technology, various aspects of the environment can be monitored to provide information for decision-making.

5.9-12.J Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> J. The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.

5.9-12.K Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> K. Humans devise technologies to reduce the negative consequences of other technologies.

5.9-12.L Students will develop an understanding of the cultural, social, economic, and political effects of technology.

L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.J Students will develop an understanding of and be able to select and use energy and power technologies.

J. Energy cannot be created nor destroyed; however, it can be converted from one form to another.

16.9-12.K Students will develop an understanding of and be able to select and use energy and power technologies.

K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.M Students will develop an understanding of and be able to select and use energy and power technologies.

M. Energy resources can be renewable or nonrenewable.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 1.4

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Principles of Engineering (PoE)

Lesson 1.4

Next Generation Science Standards

HS.PS3.3 - Energy

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.1 - Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS.ETS1.2 - Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

DCI - PS3.A - Energy - Definitions of Energy

"Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5)

DCI - PS3.A - Energy - Definitions of Energy

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2)

DCI - PS3.A - Energy - Definitions of Energy

At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Conserv ation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between sy stems. (HS-PS3-1), (HS-PS3-4)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

The availability of energy limits what can occur in any system. (HS-PS3-1)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering.

These global challenges also may have manifestations in local communities. (HS-ETS1-1)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety , reliability , and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

DCI - ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

DCI - ESS3.D - Earth and Human Activity - Global Climate Change

Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Asking questions and defining problems

Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.

Science and Engineering Practice - Asking questions and defining problems

Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.

Science and Engineering Practice - Developing and Using Models

Design a test of a model to ascertain its reliability.

Science and Engineering Practice - Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.

Science and Engineering Practice - Developing and Using Models

Develop a complex model that allows for manipulation and testing of a proposed process or system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.

Science and Engineering Practice - Planning and Carrying Out Investigations

Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Patterns

Empirical evidence is needed to identify patterns.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Changes in systems may have various causes that may not have equal effects.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

The total amount of energy and matter in closed systems is conserved.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Principles of Engineering (PoE)

Lesson 1.4

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology..

> Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

8.9-12.H Students will develop an understanding of the attributes of design.

> H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

> I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

> J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

> K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

> I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

> J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

> K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

> L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

> M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.J Students will develop an understanding of and be able to select and use energy and power technologies.

J. Energy cannot be created nor destroyed; however, it can be converted from one form to another.

16.9-12.K Students will develop an understanding of and be able to select and use energy and power technologies.

K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.M Students will develop an understanding of and be able to select and use energy and power technologies.

M. Energy resources can be renewable or nonrenewable.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.1

Next Generation Science Standards

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Crosscutting Concepts - Scale, Proportion, and Quantity

Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Crosscutting Concepts - Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Crosscutting Concepts - Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Crosscutting Concepts - Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Crosscutting Concepts - Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Crosscutting Concepts - Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Crosscutting Concepts - Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Crosscutting Concepts - Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system.

Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.1

Standards for Technological Literacy

2.9-12.Y Students will develop an understanding of the core concepts of technology.

> Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

> L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

> P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

> P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.2

Common Core State Standards for English Language Arts

AS.R.1 - Reading

Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

AS.R.2 - Reading

Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas.

AS.R.7 - Reading

Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.R.9 - Reading

Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.

AS.R.10 - Reading

Read and comprehend complex literary and informational texts independently and proficiently.

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.7 - Writing

Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 - Writing

Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Principles of Engineering (PoE)

Lesson 2.2

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

G.GMD.3 - Geometric Measurement and Dimension

Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

G.GMD.4 - Geometric Measurement and Dimension

Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.2 - Modeling with Geometry

Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

Principles of Engineering (PoE)

Lesson 2.2

Next Generation Science Standards

HS.PS1.1 - Matter and Its Interactions

Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

DCI - PS1.A - Matter and Its Interactions - Structure and Properties of Matter

The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1)

DCI - PS1.A - Matter and Its Interactions - Structure and Properties of Matter

The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Crosscutting Concepts - Scale, Proportion, and Quantity

Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Crosscutting Concepts - Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Crosscutting Concepts - Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Crosscutting Concepts - Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Crosscutting Concepts - Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Crosscutting Concepts - Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Crosscutting Concepts - Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Crosscutting Concepts - Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system.

Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.2

Standards for Technological Literacy

2.9-12.Y Students will develop an understanding of the core concepts of technology.

Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.3

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions

Interpret parts of an expression, such as terms, factors, and coefficients.

A.SSE.1.b - Seeing Structure in Expressions

Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

Principles of Engineering (PoE)

Lesson 2.3

Next Generation Science Standards

HS.PS1.3 - Matter and Its Interactions

Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

DCI - PS1.A - Matter and Its Interactions - Structure and Properties of Matter

The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

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Evaluate a question to determine if it is testable and relevant.

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Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

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Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

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Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Patterns

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

Crosscutting Concepts - Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Crosscutting Concepts - Patterns

Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments.

Crosscutting Concepts - Patterns

Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.

Crosscutting Concepts - Patterns

Mathematical representations are needed to identify some patterns.

Crosscutting Concepts - Patterns

Empirical evidence is needed to identify patterns.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Crosscutting Concepts - Scale, Proportion, and Quantity

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Crosscutting Concepts - Systems and System Models

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Crosscutting Concepts - Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Crosscutting Concepts - Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Crosscutting Concepts - Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Crosscutting Concepts - Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Crosscutting Concepts - Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Crosscutting Concepts - Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Crosscutting Concepts - Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system.

Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.3

Standards for Technological Literacy

2.9-12.Y Students will develop an understanding of the core concepts of technology.

> Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

> L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

> P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

> P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.4

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

Principles of Engineering (PoE)

Lesson 2.4

Next Generation Science Standards

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.2 - Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering.

These global challenges also may have manifestations in local communities. (HS-ETS1-1)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.

Science and Engineering Practice - Planning and Carrying Out Investigations

Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

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Crosscutting Concepts - Patterns

Empirical evidence is needed to identify patterns.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

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Crosscutting Concepts - Scale, Proportion, and Quantity

Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Crosscutting Concepts - Scale, Proportion, and Quantity

Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

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Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.4

Standards for Technological Literacy

2.9-12.W Students will develop an understanding of the core concepts of technology.

W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

2.9-12.X Students will develop an understanding of the core concepts of technology.

X. Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.

2.9-12.Y Students will develop an understanding of the core concepts of technology.

Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

2.9-12.Z Students will develop an understanding of the core concepts of technology..

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching andgenerating ideas, identifying criteria and specifying constraints, exploring possibilities,selecting an approach, developing a design proposal, making a model or prototype,

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 3.1

Next Generation Science Standards

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

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Principles of Engineering (PoE)

Lesson 3.1

Standards for Technological Literacy

2.9-12.FF Students will develop an understanding of the core concepts of technology.

FF. Complex systems have many layers of controls and feedback loops to provide information.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 3.2

Next Generation Science Standards

HS.PS3.3 - Energy

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Principles of Engineering (PoE)

Lesson 3.2

Standards for Technological Literacy

2.9-12.FF Students will develop an understanding of the core concepts of technology.

FF. Complex systems have many layers of controls and feedback loops to provide information.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 3.3

Common Core State Standards for Mathematics

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Principles of Engineering (PoE)

Lesson 3.3

Next Generation Science Standards

HS.PS3.3 - Energy

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS.ETS1.2 - Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS.ETS1.3 - Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS.ETS1.4 - Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering.

These global challenges also may have manifestations in local communities. (HS-ETS1-1)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Principles of Engineering (PoE)

Lesson 3.3

Standards for Technological Literacy

2.9-12.W Students will develop an understanding of the core concepts of technology.

W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

2.9-12.X Students will develop an understanding of the core concepts of technology.

X. Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.

2.9-12.Y Students will develop an understanding of the core concepts of technology.

Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

2.9-12.Z Students will develop an understanding of the core concepts of technology..

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.FF Students will develop an understanding of the core concepts of technology.

FF. Complex systems have many layers of controls and feedback loops to provide information.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

10.9-12.I Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

10.9-12.J Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

J. Technological problems must be researched before they can be solved.

10.9-12.K Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

K. Not all problems are technological, and not every problem can be solved using technology.

10.9-12.L Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

L. Many technological problems require a multidisciplinary approach.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 4.1

Common Core State Standards for Mathematics

S.ID.1 - Interpreting Categorical and Quantitative Data

Represent data with plots on the real number line (dot plots, histograms, and box plots).

S.ID.2 - Interpreting Categorical and Quantitative Data

Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S.ID.3 - Interpreting Categorical and Quantitative Data

Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S.ID.4 - Interpreting Categorical and Quantitative Data

Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

S.IC.1 - Making Inferences and Justifying Conclusions

Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

S.IC.2 - Making Inferences and Justifying Conclusions

Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?

S.IC.4 - Making Inferences and Justifying Conclusions

Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

S.CP.1 - Conditional Probability and the Rules of Probability

Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events (“or,” “and,” “not”).

S.CP.2 - Conditional Probability and the Rules of Probability

Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.

S.CP.3 - Conditional Probability and the Rules of Probability

Understand the conditional probability of A given B as P(A and B)/P(B), and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.

S.CP.4 - Conditional Probability and the Rules of Probability

Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.

S.CP.5 - Conditional Probability and the Rules of Probability

Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.

S.CP.6 - Conditional Probability and the Rules of Probability

Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model.

S.CP.7 - Conditional Probability and the Rules of Probability

Apply the Addition Rule, P(A or B) = P(A) + P(B) – P(A and B), and interpret the answer in terms of the model.

S.CP.8 - Conditional Probability and the Rules of Probability

(+) Apply the general Multiplication Rule in a uniform probability model, P(A and B) = P(A)P(B|A) = P(B)P(A|B), and interpret the answer in terms of the model.

S.CP.9 - Conditional Probability and the Rules of Probability

(+) Use permutations and combinations to compute probabilities of compound events and solve problems.

S.MD.7 - Using Probability to Make Decisions

(+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

Principles of Engineering (PoE)

Lesson 4.1

Next Generation Science Standards

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Principles of Engineering (PoE)

Lesson 4.1

Standards for Technological Literacy

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 4.2

Common Core State Standards for English Language Arts

AS.W.5 - Writing

Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.7 - Writing

Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 - Writing

Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Principles of Engineering (PoE)

Lesson 4.2

Common Core State Standards for Mathematics

N.RN.2 - The Real Number System

Rewrite expressions involving radicals and rational exponents using the properties of exponents.

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

N.VM.1 - Vector and Matrix Quantities

(+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v).

N.VM.2 - Vector and Matrix Quantities

(+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point.

N.VM.3 - Vector and Matrix Quantities

(+) Solve problems involving velocity and other quantities that can be represented by vectors.

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions

Interpret parts of an expression, such as terms, factors, and coefficients.

A.SSE.1.b - Seeing Structure in Expressions

Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

A.CED.3 - Creating Equations

Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non- viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A.CED.4 - Creating Equations

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

A.REI.3 - Reasoning with Equations and Inequalities

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A.REI.4 - Reasoning with Equations and Inequalities

Solve quadratic equations in one variable.

F.TF.7 - Trigonometric Functions

(+) Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context.

G.SRT.6 - Similarity, Right Triangles, and Trigonometry

Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

G.SRT.8 - Similarity, Right Triangles, and Trigonometry

Use trigonometric ratios and the Pythagorean theorem to solve right triangles in applied problems.

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

S.ID.2 - Interpreting Categorical and Quantitative Data

Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

Principles of Engineering (PoE)

Lesson 4.2

Next Generation Science Standards

HS.PS2.1 - Motion and Stability: Forces and Interactions

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS.PS3.3 - Energy

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

DCI - ETS1.B - Engineering Design - Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety , reliability , and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

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Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Principles of Engineering (PoE)

Lesson 4.2

Standards for Technological Literacy

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

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CURRICULUM FRAMEWORK

COURSE: Honors Anatomy **GRADE: 11 and 12**

Unit	Standards	Unit Concept/Essential Questions	Assessments
Unit 1- THE HUMAN BODY: AN ORIENTATION Chapter 1	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2 HS-LS1-3	Essential Questions • What is anatomy? • What are the requirements for human life? Learning Objectives Student will be able to… 1. Define the term anatomy. 2. Define and use common Latin roots, prefixes and suffixes. 3. Describe how observation is used to see the sizes and relationships of body parts. 4. Name the levels of structural organization the make up the human body and explain how they are related. 5. Define homeostasis and explain its importance in maintaining life. 6. Use proper anatomical terms to describe body directions, surfaces, & planes. 7. Locate the major body cavities and list the chief organs in each cavity. 8. Name the organ systems of the body and describe the major functions of each. Content Specific Vocabulary Anatomy, Observation, Homeostasis, Levels of Organization, Atom, Molecule, Cell, Tissue Organ, Organ System, Organism, Directional terms, surfaces and planes,Body Cavities	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Virtuvian Man Lab- Student analyze their own body symmetry and calculate body proportions and ratios using standard body-metrics data. Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 1 Unit test Performance Tasks:

TEACHER'S NAME: Jennifer Couch **6/17**

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			Anatomy Man Project- Students create a model human and then create a story based on anatomical terms they have randomly chosen from a bag and read the story to the class.
Unit 2- BASIC CHEMISTRY Chapter 2	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-PS1-1 HS-PS1-2 HS-LS1-6	Essential Question: • What is the relationship between matter and energy as it relates to the human body? Learning Objectives: Students will be able to… 1. Differentiate between matter and energy. 2. Explain the relationship between subatomic particles and elements. 3. List the 4 elements that make up the bulk of body matter. 4. Recognize that chemical reactions involve the interaction of electrons to make and break chemical bonds. 5. Differentiate between ionic, covalent, and hydrogen bonds 6. Compare and contrast synthesis, decomposition, single-replacement, and double replacement reactions. 7. Describe the importance of selected salts in body functioning. 8. Distinguish between organic and inorganic molecules. 9. Name and describe the 4 major classes of macromolecules including their building block molecules and their major functions. 10. Describe the roles of water in body functioning. 11. Explain the role of enzymes.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Great Ion Bead Game Ion Speed Date Activity McMush Murder Lab Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point

		Content Specific Vocabulary: Matter, Energy, Atom, Proton, Neutron, Electron, Isotope, Ion, Cation, Anion, Chemical reactions, Covalent bond, Ionic Bond, Hydrogen Bond, Synthesis, Decomposition, Single Replacement, Double, Replacement, Organic, Inorganic, Macromolecule, Carbohydrate, Protein, Lipid, Nucleic, Acid, Activation energy, Reactants, Products, Enzymes, Endothermic, Exothermic, Active site, Denature, ATP	presentation) Summative: Tests/ Labs: Chapter 2 Unit Test Performance Tasks: Present Findings of McMush Murder Lab
Unit 3- CELLS AND TISSUES Chapter 3	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2	Essential Questions: • How do cells and the organelles within them work together to form the basis of all life? • How and why do cells differentiate? • What are tissues and how are they classified? Learning Objectives: Students will be able to… 1. Define, identify, and explain the function of a typical animal cell and its organelles. 2. Describe the processes that move substances into and out of cells. 3. Describe the process of DNA replication and mitosis 4. Describe the functions of the 3-types of RNA & the process of protein synthesis. 5. Name and contrast the 4 major types of tissue. 6. Describe the chief locations of the various body tissue types. 7. Describe the process of tissue repair. 8. Describe the characteristics of a neoplasm.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Genetic Code Relay Game Cell Specialization Virtual Lab Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at

		Content Specific Vocabulary: Cell, Organelle, Homeostasis, Passive transport, Diffusion, Osmosis, Hypertonic, Hypotonic, Isotonic, Facilitated diffusion, Active transport, Molecular pumps, Endocytosis, Exocytosis Differentiation, Daughter cells, Sister chromatids, Centrioles, Spindle fibers, Cell cycle, Interphase, Mitosis, Prophase, Metaphase, Anaphase, Telophase, Cytokinesis, Cleavage furrow/ Cell plate, Cancer, Carcinogen, Malignant, Benign, Tissues, Connective tissue, Nervous tissue, Muscle tissue, Epithelial tissue, Regeneration, Fibrosis	home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 3 Unit Test Performance Tasks: Students create a “secret code” using an amino acid sequence- Other students use the codon chart to try to solve.
Unit 4- SKIN AND BODY MEMBRANES Chapter 4	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2	Essential Question: • What are membranes? • How does the structure of a membrane impact its function? • What is the function of skin? • How does the structure of skin impact is function? Learning Objectives: Student will be able to: 1. List the general functions of the 4 types of membranes and describe their location in the body. 2. Describe the functions of the integumentary system. 3. Name and describe the functions of the major proteins of the integumentary system.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Touch- Test Lab- Student create probes and test the sensitivity of different body regions

		4. Locate and describe selected skin layers, structures, and derivatives. 5. Describe the cause and pathology of selected skin disorders. Content Specific Vocabulary: Membrane, Cutaneous, Mucous, Serous, Synovial, Integumentary System, Epidermis, Dermis, Sebaceous gland, Hair follicle, Melanin, 1st, 2nd, 3rd degree burns, Rule of Nines, Basal cell carcinoma, Squamous cell carcinoma, Melanoma	How Much Skin Do You Have- Student take body measurements to complete skin surface area calculations – Important for the Rule of Nines Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 4 Unit Test Performance Tasks: • Skin disease and disorder research presentations
Unit 5- THE SKELETAL SYSTEM	*Next Generation Science Standards by NSTA and*	Essential Question: • What are the major divisions of the skeletal system and how do we differentiate between them. • What are the major structures of long bones?	The following assessments will provide evidence of student learning: Formative:

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COURSE: Honors Anatomy **GRADE: 11 and 12**

Chapter 5	*Delaware Department of Education:* HS-LS3-1 HS-LS3-2	• What are the major types of joints? • What are ways to increase bone density and integrity? • What role do age and gender have in bone growth and formation? Learning Objectives: Student will be able to: 1. Identify the subdivisions of the skeleton as axial or appendicular. 2. List and describe the major functions of the human skeleton. 3. Classify bones on the basis of shape and relate the shape to the function of a bone. 4. Describe and identify the types of bone markings and their functions. 5. Identify all 206 bones of a human skeleton in diagram, model, & disarticulated skeletons. 6. When given a picture or x-ray be able to name and describe various types of fractures. 7. Describe 3 major categories of joints; compare the amount of movement allowed by each. 8. Distinguish between male, female, infant, child, & adult skeleton samples and fragments. 9. Describe the process of bone formation and bone aging. Content Specific Vocabulary: Axial, Appendicular, Osetocyte, Osteoblast, Osteoclast, Osteoporosis Articulation, Ligament, Fracture, Dislocation, Joint, Scoliosis, Lordosis, Kyphosis, Osteoporosis	Daily Vocab Slam quizzes via Schoology • Classwork/Labs: Unearthing 17th Century Chesapeake-A Forensic Science “Bone” Lab • Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: • Tests/ Labs: Chapter 5 Unit Test Disarticulated Skeleton Practicum Performance Tasks: What do these bones tell? Given a set of bones and historical clues student create a plausible “life-story” for the

			person the bones belong to.
Unit 6- BLOOD Chapter 10	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS1-1 HS-LS1-2	Essential Question: • What are the structures and functions of blood? Learning Objectives: Student will be able to: 1. Describe the transport and heat distributing functions of the blood. 2. Describe the composition of blood plasma. 3. Name the formed elements of the blood and describe the major functions of each. 4. Describe causes, symptoms, & problems associated w/ anemia, leukemia, & hemophilia. 5. Explain the basis for a blood transfusion reaction. 6. Name the sites and cells involved in blood cell formation. Content Specific Vocabulary: Plasma, Formed elements, Leukocyte, Erythrocyte, Thrombocyte, Hematopoesis, Anemia, Polycythemia, Leukopenia, Leukocytosis, Hemocyoblast, Hemophilia, ABO blood typing, Rh factor Jaundice	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Blood typing lab- Using synthetic blood students determine blood types using the ABO- Rh blood typing systems Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 5 Unit Test

			Genetics of Blood Quiz Performance Tasks: Given specific blood type genotypes students will be able to calculate and predict blood types of offspring
Unit 7- THE CARDIOVASCULAR SYSTEM Chapter 11	*Next Generation Science Standards by NSTA and Delaware Department of* Education: HS-LS2-1 HS-LS2-2	Essential Question: • What are the structures of the cardiovascular system? • How does the heart pump blood? • What are the 3 types of vessels that make up the cardiovascular system and what are their general functions? Learning Objectives: Student will be able to: 1. Trace the path of blood through the heart & lungs naming chambers, valves, & vessels. 2. Describe the cardiac cycle. 3. Describe the influence of selected factors on cardiac output. 4. Describe the pathway & parts of impulses through the intrinsic conduction system. 5. Explain what information can be gained from an electrocardiogram. 6. Describe normal blood pressure and list factors that affect it. 7. Describe the exchanges that occur across capillary walls. 8. Locate, name, and identify areas served by each of the arterial branches of the aortic arch.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Heart Dissections Heart Rate Lab- Learn how to take radial or corroded pulses and investigate factors that influence heart rate including exercise and meditation Homework:

		9. Locate and name selected arteries and veins and describe the areas served by each. Content Specific Vocabulary: Cardiovascular system, Heart, Artery, Vein, Capillary, Pulmonary circulation, Systemic Circulation, Intrinsic conduction system, Systole, Diastole, Stroke volume, Cardiac cycle, Murmur, Blood pressure, Pulse, Hypertension, Atherosclerosis	Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 7 Unit Test Performance Tasks: Students will be able to take a patient's blood pressure using a sphygmomanometer
Unit 8 - THE LYMPHATIC SYSTEM Chapter 12	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1	Essential Question: • What is the lymphatic system and what is its role in human health? • What are the structures of the lymphatic system? • What are other body defense mechanisms and what is their role in human health? Learning Objectives: Student will be able to: 1. Name the two major types of structures composing the lymphatic system & explain how the lymphatic system is functionally related to the cardiovascular and immune systems. 2. Describe the composition of lymph and explain its formation and transport. 3. Identify location & function of tonsils, nodes, thymus, Peyer's patches, & the spleen.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Hand Sanitizers – Helpful or Harmful Lab- Students design a lab investigation

	HS-LS2-2	4. Describe the protective functions of skin, mucous membranes, phagocytes, natural killer cells, fever, interferon and gastric juice. 5. Describe the role of selected defensive structures & responses as specific or nonspecific. 6. Describe the role of T cells and B cells in the immune response. 7. Name the types of acquired and natural immunity and describe the source of each. 8. Describe the function of selected cells involved in the immune response. 9. Name the cause and describe the pathology of selected diseases. Content Specific Vocabulary: Lymphatic system, Lymph, Lymph nodes, Tonsils, Thymus, Peyer's patches, Spleen, Edema, Pathogen, Phagocytes, Inflammatory process, Fever, Antigen, Hapten, Lymphocytes, B cells, T cells, Macrophage, Antibodies, Active immunity, Passive immunity, Immunodeficiency, Allergies, Autoimmune disease	to analyze the effectiveness of various soaps and hand sanitizer and then draw conclusions about the implications of the data they collect. Who's Immune? – Students investigate diseases like Ebola, Black Death, Typhoid fever and HIV to gain an understanding of how diseases are spread and how one can become immune to them. (Natural or Acquired immunity) Also, students will be able to pinpoint the evolutionary cause of "super bugs" like MRSA. Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs:

			Chapter 8 Unit Test Performance Tasks: Students present their "Who's Immune" research. Student will model the proper hand washing technique to decrease the spread of disease.
Unit 9- THE MUSCULAR SYSTEM Chapter 6	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1 HS-LS2-2	Essential Question: • What is the general structure and function of muscles? • What are the 3 types of muscles and how can one differentiate between them? • What is the major smooth muscle in the human body? • What are the major skeletal muscles in the human body? Learning Objectives: Student will be able to: 1. Identify similarities, differences, and locations of the 3 types of muscle. 2. Link "origin, insertion, prime mover, antagonist, synergist, & fixator" to muscle actions. 3. Demonstrate and identify the different types of body movements 4. Name and locate the major muscles of the human body. 5. Describe the origin, insertion, and action of selected muscles. 6. Describe the structures that form the anatomy of a muscle. 7. Name the primary muscle proteins.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Gross Skeletal Muscle Identification Lab Bust-a-Move: Students create a hand-shake or dance that uses all of the major body movements. Homework:

		Content Specific Vocabulary: Muscle fiber, Skeletal muscle fiber, Voluntary, Involuntary, Straitions, Endomysium, Perimysium, Epimysium, Tendons, Smooth muscle, Cardiac muscle, Sarcolemma, Myofibril, I band, A band, Sarcomeres, Myofilaments, Actin, Myosin, Neurotransmitter, Acetylcholine (Ach), Action Potential, Flexion, Extension, Rotation, Abduction, Adduction, Circumduction, Dorsiflextion, Plantar flexion, Inversion, Eversion, Supination, Pronation, Opposition, Fixator, Synergist, Prime mover, Antagonist, Origin, Insertion	Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 9 Unit Test Skeletal Muscle ID Quiz Performance Tasks: Bust-a-Move: Students present the hand-shake or dance they created that uses all of the major body movements.
Unit 10- SPECIAL SENSES Chapter 8	*Next Generation Science Standards by NSTA and Delaware Department of Education:*	Essential Question: How do special senses respond to different types of energetic stimuli involved in vision, hearing, balance, smell, and taste? Learning Objectives: Student will be able to: 1. Identify the accessory structures of the eye in a model or diagram and list their functions. 2. Name the eye tunics and describe the functions of each. 3. Explain the difference between rod and cone function.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs:

	HS-LS2-1 HS-LS2-2	4. Trace pathway of light through the eye to the retina & visual pathway to the optic cortex. 5. Identify the structures & functions of the external, middle & internal ear. 6. Describe the location, structure, and function of the olfactory and taste receptors. Content Specific Vocabulary: Special sense receptors, ANATOMY OF THE EYE- External and Accessory Structures: eyelid, medial and lateral commissure, canthus, eyelashes, tarsal glands, conjunctiva, lacrimal, lysosome Extrinsic and external eye muscles, Internal Structures: Eyeball, Tunics, Sclera, Cornea, Fibrous Layer, Vascular layer, Choroid, Ciliary zonule, Iris, Pupil, Sensory layer, Retina, Photoreceptors, Rods, Cones, Optic nerve, Blind spot, Optic Disc, Fovea centralis, Lens, Cataracts, Glaucoma ANATOMY OF THE EAR- Mechanoreceptors, External Ear- Auricle, Pinna, Cerumen, External acoustic meatus, tympanic membrane, Middle Ear- Tympanic cavity, Oval window, Round window, Pharyngotympanic tube, Ossicles, Osseous labyrinth, Cochlea, Vestibule, Semicircular canals, Static and Dynamic equilibrium, Hair Cells TASTE BUDS AND THE SENSE OF TASTE- Taste buds, Papillae, Circumvallate and Fungiform papillae, Gustatory Cells, Taste pore, Glossopharyngeal, Vagus	Eye dissections Can You Be A Fighter Pilot? – Student test their visual acuity, peripheral vision and balance using standardized tests. Colorblindness Tests Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 10 Unit Test Eye Anatomy Quiz Ear Anatomy Quiz Tongue Anatomy Quiz Performance Tasks: Hearing Safety Public Safety

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COURSE: Honors Anatomy **GRADE: 11 and 12**

			Announcement – Post to Hawk News
Unit 11- THE NERVOUS SYSTEM Chapter 7	Next Generation Science Standards by NSTA and Delaware Department of Education: HS-LS2-1 HS-LS2-2	Essential Question: How does the nervous system maintain body homeostasis with electrical signals; provide for sensation, higher mental functioning, and emotional response? Learning Objectives: Student will be able to: 1. List the general function of the nervous system. 2. Explain the structural and functional classifications of the nervous system. 3. Describe the major parts of the central nervous system and peripheral nervous system. 4. State the functions of neurons and neuroglia. 5. Describe the functions of the major regions of the cerebral hemispheres, diencephalons, brain stem, and cerebellum & identify their location on a human brain model or diagram. 6. Describe the general structure and function of a nerve. 7. Name and describe protective structures of the central nervous system. 8. Describe spinal cord structure. 9. Describe the areas served by selected plexuses and nerves. 10. Describe the electrical & chemical events involved in transmission of a nerve impulses. Content Specific Vocabulary: Nervous system, Stimulus, Sensory input, Integration, Motor output, Central nervous system, Peripheral nervous system, afferent, efferent, somatic, voluntary, autonomic, involuntary, Neuroglia, Oligodendrocytes, Asrocytes, Axon, Dendrite, Schwann cell, Axon terminal, Neurotransmitter, Synapitic cleft, Synapse, Nodes of Rnavier, Mutiple Sclerosis, Cerebral Hemisphere, Gyri, Sulci, Fissures, Lobes, Cerebrum, Cerebral cortex, Grey matter, White matter, Brain stem, Midbrain,	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Brain Dissections Brain Hat- Student make a model of the basic structures of the brain that they can wear as a hat. Reaction Rate Lab- Students investigate reaction rate and factors such as listening to music and texting that effect reaction rate Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point

		Medulla oblongata, Cerebellum, Huntington's disease, Parkinson's, Alzheimer's	presentation) Summative: Tests/ Labs: Chapter 11 Unit Test Anatomy of the Brain and Neuron Quiz Performance Tasks: Nervous System Disease Disorder Presentation
Unit 13- THE RESPIRATORY SYSTEM Chapter 13	Next Generation Science Standards by NSTA and Delaware Department of Education: HS-LS2-1 HS-LS2-2	Essential Question: How does the respiratory system supply the blood with oxygen while removing carbon dioxide? Learning Objectives: Student will be able to: 1. Name and locate the structures forming the respiratory passageway form the nasal cavity to the alveoli and describe the function of each. 2. Describe the protective mechanisms of the respiratory system. 3. Describe the mechanics of breathing. 4. Describe the various respiratory volumes and capacities. 5. Describe the process of gas exchange in the lungs and tissues. 6. Describe physical, emotional & chemical factors that influence respiratory rate and depth. 7. Describe the causes and pathology of selected respiratory disorders.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Calculating Respiratory Volume Lab Vape Debate- Is vaping better than smoking? Are vape advertisers targeting teens?

		Content Specific Vocabulary: Respiratory system, nose, Bronchi, Trachea, Lungs, Pulmonary, Pleura, Bronchioles, Alveoli, Respiratory membrane, Pulmonary ventilation, External respiration, Respiratory gas transport, Internal respiration, Diaphragm, Dead space volume, spirometer, Hypoxia, Carbon monoxide poisoning, CPD, Asthma, Hyperpnea, Apnea, Chronic Bronchitis, Emphysema, Cystic Fibrosis, IRDS, SIDS, Sleep apnea	Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 13 Unit Test Performance Tasks: Respiratory System Disease Disorder Presentation
Unit 14 - THE DIGESTIVE SYSTEM Chapter 14	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1	Essential Question: • What are the structures of the digestive system? • How does the digestive system break down ingested food into particles small enough to ab absorbed into the blood? Learning Objectives: Student will be able to: 1. Locate, name, describe the structure, and describe the functions of organs and accessory organs of the digestive system. 2. Describe the composition and functions of saliva, gastric juice, and bile. 3. Describe & locate the villi in the digestive tract & explain how they aid digestive process.	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Digestive System Puzzle Model- Students are given the digestive system

	HS-LS2-2	4. Describe the source and digestive functions of selected hormones and enzymes. 5. Name the end products of protein, fat, and carbohydrate digestion. Content Specific Vocabulary: Chemical digestion, Mechanical digestion, Alimentary canal, Gastrointestinal (GI) tract, Mastication, Mouth, Esophagus, Pharynx, Stomach, Small intestine, Large intestine, Sphincter, Villi, Microvilli, Peristalsis, Bolus, Chyme, Liver, Pancrease, Gall bladder, Bile, Duodenum, Jejunum, Ileum, Appendix, Colon, Rectum, Cecum, Anal canal, Salivary glands, Absorption, Defecation, Ingestion, Propulsion, _Macromolecules, Carbohydrates, Monosaccharide, Protein, Amino acid, Lipid, Triglyceride, Celiac disease, IBS, Villi atrophy	organs and have to identify they and put them in the correct or and sequence Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 14 Unit Test Digestive System Anatomy Quiz Performance Tasks: Sham-Wow to Oh-No….Modeling intestinal villi disorders
Unit 15- THE URINARY SYSTEM Chapter 15	*Next Generation Science Standards by NSTA and Delaware*	Essential Question: How does the urinary system rid the body of nitrogenous wastes while regulating water, electrolyte, and acid-base balance of the blood? Learning Objectives: Student will be able to:	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via

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COURSE: Honors Anatomy **GRADE: 11 and 12**

	Department of Education: HS-LS2-1 HS-LS2-2	1. Describe the location & functions of the organs & major structures of the urinary system. 2. Identify the regions of a kidney and their functions. 3. Describe the structure and function of a nephron. 4. Describe the process of urine formation. 5. Identify mechanisms involved in regulating water, electrolytes, & pH levels of blood. 6. Describe the composition of normal urine. 7. List the causes of selected abnormal urinary components. 8. Describe three common urinary tract problems. Content Specific Vocabulary: Urinary system, Kidney, Nephron, Glomerulus, Bowman's capsule, Ureter, Urethra, Bladder, Urine, Urea, Voiding, Micturition, Incontinence, Intracellular Fluid, Extracellular fluid, Thirst mechanism, Diabetes insipdus, Polyurea, Alkalosis, Acidosis	Schoology Classwork/Labs: Urinalysis Lab- Students use simulate urine to test for diabetes, and short term and long term infections Need for Speed = Homeostatic Imbalance Debate Homework: Text book- Did You Get It? Questions Flipped Notes (Cornell Notes- taken at home using videoed Power Point presentation) Summative: Tests/ Labs: Chapter 15 Unit Test Urinary System Anatomy Quiz Performance Tasks: The Obesity Epidemic CSET- Students will construct an argumentative

			paragraph using professional medical resources that argues the claim that the "convenience life-style" of America has created the obesity epidemic, which has lead to a nation-wide diabetes problem.
Unit 16 - THE REPRODUCTIVE SYSTEM Chapter 16	*Next Generation Science Standards by NSTA and Delaware Department of Education:* HS-LS2-1 HS-LS2-2	Essential Question: What is the evolutionary advantage of sexual reproduction? What are the structures, functions and purpose of the male reproductive system? What are the structures, functions and purpose of the female reproductive system? Learning Objectives: Student will be able to: 1. Explain how meiosis differs from mitosis. 2. Describe functions & locations of selected structures that form the reproductive systems. 3. Describe the processes of spermatogenesis and oogenesis. 4. Describe the phases and controls of the menstrual cycle. 5. Describe the stages of embryonic development. 6. Describe the stages of labor and how labor is initiated. 7. Explain the origin and functions of the placenta, chorion, and the amnion. 8. Describe physiological changes that occur in selected systems of a pregnant female. Content Specific Vocabulary: Sexual reproduction, meiosis, spermatogenesis, oogenesis, menstrual cycle, embryo, fetus	The following assessments will provide evidence of student learning: Formative: Daily Vocab Slam quizzes via Schoology Classwork/Labs: Male, Female and Embryonic Development Cornell Notes Homework: Text book- Did You Get It? Questions Summative: Tests/ Labs: Chapter 14 Unit Test

			Male Reproductive System Anatomy Quiz, Female Reproductive System Anatomy Quiz

Course: Honors Biology

Unit 6 Evolution

Unit Plan

Essential Question: How to species change over time to survive in different environmental conditions?

Content Specific Vocabulary:

- Natural selection, Biological evolution, Microevolution, Macroevolution, Fitness, Gene pool, Genetic drift, Gene flow, Sexual selection, Genetic equilibrium, Hardy-Weinberg principle
- Gradualism, Punctuated equilibrium, Adaptive radiation, Divergent evolution, convergent evolution, Co-evolution, Extinction, (gradual and mass), Sexual and asexual reproduction
- Biogeography, Anatomy, Homologous structures, Analogous structures, Embryology, Biochemistry, Paleontology, Fossils, Transitional fossils
- Taxonomy, Phylogeny, Phylogenetic tree

Day	Learning Objectives	Methods/Activities	Assessments Formative & Summative	Homework Formative	NGSS Standards
1	Introducing Evolution	-Evolution pre-survey -Have half of students read story about Darwin and the other half read about Wallace. Answer questions throughout reading -Discuss readings and survey results -Start Concept 1 Notes on what was believed before and principles of natural selection p.2-4	Formative -Informal questioning and discussion	-Work on Concept 1 SG	HS-LS3-2 HS-LS4-2 HS-LS4-4
2	Natural Selection	-Finish Concept 1 Notes on principles of natural selection that you didn't yesterday (stop at end of p.4) -Principles of Natural Selection Practice p.10-11, go over after -Natural Selection Lab p.12-14, get data, start graph. Students must finish analysis and conclusion for homework	Formative -Informal questioning and discussion	-Finish Natural Selection Lab p.12-14 -Work on Concept 1 SG	HS-LS4-2 HS-LS4-4
3-5	Modes of Selection Allele Frequencies Microevolution Genetic Equilibrium	-Collect Natural Selection Labs p.12-14 -Concept 1 Notes on Modes of Selection on the top of p.5 -Modes of Selection Practice p.15, go over after -More Concept 1 Notes p.5-7 (as much as you can) -Cards demo for genetic drift	Summative -Natural Selection Lab p.12-14 Formative -Informal questioning and discussion	-Work on Concept 1 SG	HS-LS4-3 HS-LS4-5

6	Allele Frequencies Hardy-Weinberg Equilibrium	-Finish Concept 1 Notes p.7-9 -HWE Practice #1 p. 16-18, together as a class -HWE Practice #2 p.19-21 – will be collected and graded for accuracy tomorrow	**Formative** -Informal questioning and discussion	-Finish HWE #2 p.19-21 -Work on Concept 1 SG	HS-LS4-3 HS-LS4-5
7	Evolution	-Collect HWE Practice #2 p.19-21 to grade for accuracy -Evolutionary Arms Race Video and questions p.22-23 -Work on Concept 1 SG after	**Formative** -HWE Practice #2 p.19-21 -Evo. Arms Race Video questions p.22-23 -Informal questioning and discussion	-Finish Concept 1 SG	HS-LS3-2 HS-LS4-2 HS-LS4-3 HS-LS4-4 HS-LS4-5
8	Patterns of Macroevolution	-HWE Quiz -Concept 2 Notes p.24-25 -Patterns of Evolution Practice p.26, go over after	**Summative** -HWE Quiz **Formative** -Informal questioning and discussion	-Concept 2 SG	HS-LS4-2 HS-LS4-3 HS-LS4-4 HS-LS4-5
9	Patterns and Evidence of Evolution	-Collect Concept 2 SG -Concept 3 Notes p.27-28 -Lab Stations Activity: Exploring Evolution p.29-30	**Formative** -Concept 2 SG -Informal questioning and discussion	-Work on Concept 3 SG	HS-LS4-1 HS-LS4-4
10	Patterns and Evidence of Evolution Phylogeny	-Finish Lab Stations Activity p.29-30, collect or go over. -Evolution Vocabulary Practice p.31 -Concept 4 Notes p.32-34 -Phylogenetic Tree Practice #1 p.35 (students may have to finish for HW)	**Formative** -Lab Stations Activity p.29-30 -Informal questioning and discussion	-Finish Concept 3 SG -Finish Phylogenetic tree practice #1 p.35 (as needed)	HS-LS4-1 HS-LS4-4 HS-LS4-5
11	Phylogeny	-Collect Concept 3 SG -Check and go over phylogenetic tree practice #1 p.35 -Tree Practice #2 p.36 -Putting it All Together Practice on p.37-38	**Formative** -Informal questioning and discussion	-Finish Concept 4 SG	HS-LS4-1
12	Review	-Collect Concept 4 SG -Review	**Formative** -Collect Concept 4 SG -Informal questioning and discussion	-Study for test	HS-LS3-2 HS-LS4-1 HS-LS4-2 HS-LS4-4 HS-LS4-5
13	Test	-Unit 6 Evolution Test: Concepts 1-4 + Cumulative	**Summative** -Test		HS-LS3-2 HS-LS4-1 HS-LS4-2 HS-LS4-3 HS-LS4-4 HS-LS4-5

Course Title: Algebra I (8^{th} / 9^{th} Grade)

Unit Title: 1A – Numbers and Expressions

Name(s) of Teacher(s) who Developed Unit: Carla M. Costa

Dates Developed: June 2017

Approximate Time when Taught During School Year: September

Approximate Number of Periods: 10 (90-minute periods)

Summary: In this unit, students learn about and model relationships using precision, significant digits, dimensional analysis, exponents, real numbers, evaluating, simplifying, and writing expressions.

Print Materials Needed: Textbook

Resources: Houghton Mifflin Harcourt Algebra 1:Analyze, Connect, Explore

Internet Resource Links: my.hrw.com

Stage 1: Desired Results

Essential Questions:

Module 1 – Relationships Between Quantities

- How do you calculate when the numbers are measurements?
- How do you use significant digits when reporting the results of calculations involving measurement?
- How can you use dimensional analysis to convert measurements?

Module 2 – Exponents and Real Numbers

- What sets of numbers are included in the real numbers?
- How are radicals and rational exponents related?
- What are the subsets and properties of real numbers?

Module 3 – Expressions

- How can you use algebraic expressions to solve problems?
- How do you evaluate and interpret algebraic expressions?
- How do you simplify algebraic expressions?
- How do you write algebraic expressions to model quantities?

Know	Understand	Do
<u>Vocabulary:</u> Precision Significant Digits Dimensional Analysis Conversion Factor Exponent Index Radical Symbol Radical Expression Radicand Rational Numbers Irrational Numbers Real Numbers Integers Whole Numbers Natural Numbers Closed Set Coefficient Numerical Expression	<u>Students will understand:</u> How to choose a level of accuracy appropriate to limitations on measurement when reporting quantities. How to use units as a way to guide the solution of multi-step problems. How the definition of rational exponents follows from extending the properties of integer exponents to those values, allowing for radical notation in terms of exponents. Why the sum or product of two rational numbers is rational and why an irrational number is irrational. Why the product of a nonzero rational number and an irrational number is irrational. How to interpret expressions that	<u>The Students will be Able to:</u> Apply dimensional analysis to convert between units Do calculations using significant digits Evaluate exponential and radical expressions Model Relationships with Variables Simplify and Evaluate Expressions and Formulas Simplify and Evaluate Expressions with Grouping Symbols Classify Numbers Compare Numbers

Algebraic Expression Order of Operations Equivalent Expressions Like Terms Simplify	represent a quantity in terms of its context. How to rewrite expressions in terms of equivalent expressions. How to use appropriate quantities for the purpose of descriptive modeling.	

Stage 2: Assessment Evidence

Assessments/Performance Tasks	Rubric Titles
Lesson Quizzes - Formative Modules 1,2,3 Quizzes – Formative Unit 1A Test - Summative Unit 1A Performance Task – Summative	Assessment Readiness Item Specific Rubric (#'s 6 & 7)

Self-Assessments	Other Evidence, Summarized
Modules 1, 2, 3: Are you Ready? - Formative Modules 1, 2, 3: Ready to Go On? - Summative	Unit Review Assessment Readiness

Stage 3: Learning Activities

Math in Careers – Formative

Unit Project: Prices at the Pump - Summative

Delaware Model Unit Gallery Template

Unit Title: Arabia and Golden Age (500-1100CE)

Designed by: M McLaughlin

District: Sussex Academy

Content Area: Social Studies

Grade Level(s): 7

____

Summary of Unit

Students will examine unique physical and cultural characteristics of medieval Arabia including the formation and spread of Islam as well as the scientific and artistic achievements of the Golden Age of Arabia.

Stage 1 – Desired Results

What students will know, do, and understand

____

Delaware Content Standards

- Geography Standard Three 6-8b**:** Students will evaluate a location's site and situation in order to identify and explain the distinctive cultural and physical characteristics, patterns of trade, and interactions that make a place unique

- History Standard Four 6-8b: Students will develop an understanding of ancient and medieval world history and the continuing influence of major civilizations including:
    - Classical traditions, major religions and great empires
    - Expanding zones of exchange and encounter

Common Core Standards

- CCSS.ELA-Literacy.RH.6-8.1
  Cite specific textual evidence to support analysis of primary and secondary sources.
- CCSS.ELA-Literacy.RH.6-8.2
  Determine the central ideas or information of a primary or secondary source; provide an accurate summary of the source distinct from prior knowledge or opinions.
- CCSS.ELA-Literacy.RH.6-8.4
  Determine the meaning of words and phrases as they are used in a text, including vocabulary specific to domains related to history/social studies.

- CCSS.ELA-Literacy.RH.6-8.7
  Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.
- CCSS.ELA-Literacy.RH.6-8.9
  Analyze the relationship between a primary and secondary source on the same topic.

Big Idea(s)

- Students will understand the influence of physical geography in the region of Arabia
- Students will understand formation and basic tenet of a major world religion
- Students will evaluate contributions of Arab scientists and artists to modern world

Unit Enduring Understanding(s)

Accurate factual knowledge about the religion of Islam to better understand current world events

Ability to support claims with documented evidence

Unit Essential Questions(s)

- How did site and situation affect culture of the Arabian Peninsula?
- How did the developments of the Golden Age of Arabia influence the world today?

Knowledge and Skills

- Research historical phenomena
- Establish claim and evidence

Students will know…

- Physical and cultural characteristics
- Patterns of trade
- Contributions of medieval scholars

Students will be able to…

- Evaluate location for site and situation
- Determine their own claim and support with historical information

Stage 2 – Assessment Evidence

Evidence that will be collected to determine whether or not Desired Results are achieved

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Suggested Performance/Transfer Task(s)

Students will research artistic and scientific contributions of Golden Age of Arabia using various text and Internet resources, culminating in a multi paragraph informative response.

Golden Age of Islam Project

Similar to Ancient Greece and Rome, the Islamic Empire had a time of great achievement and innovation. **The Golden Age of Islam (800-1100**) saw the development of new ideas in many areas such as literature, architecture, math, and medicine. You will research some of these great achievements and create a project that is inspired by the artistic styles of the time period.

Your main task is to research the many and varied achievements of this time period in order to write an informative paragraph explaining TWO achievements in the area of the arts – literature, music, design, architecture or philosophy- **and** TWO achievements in the area of the sciences – mathematics, medicine, astronomy, or technology. In addition to the written response you will create a visual representation of the achievements using artistic styles of the time - geometric patterns, detailed designs and calligraphy. (Don't worry – I will show you some models)

Step One: **Gather information**. Using the following resources gather information about the many achievements of the Golden Age. *REMEMBER THE NOTE-TAKING RULES.* You are writing an informative piece so you are thinking **details and sub details**. In addition to providing information about the achievements you must explain **how each achievement affected the modern world**.

You may use ***ONLY*** the following resources: **Medieval Times 1.4 p. 28-33**
History Alive p. 107-116
Resource articles provided in class
www.1001inventions.com
www.muslimheritage.com
www.IbnAlHaytham.com

Step Two: **Complete organizer**. Once you have completed the initial gathering of information, work on completing the organizer. Understand you may need to complete additional research to 'fill any gaps' in the organizer. **Be sure to complete ALL parts of the organizer**.

Step Three: **Write and edit your rough draft.** This can be hand-written or typed, but a copy must be glued in your INB. Evidence or self and/or peer editing is required [Symbol]

Step Four: **Type or neatly write final draft.** More details to come; maybe big index cards.

Organizer for ***Golden Age of Islam*** Written Response

Skinny Introduction: ______________________________

(Explain Golden Age/importance) ______________________________

(2-3 sentences) ______________________________

Body Paragraph #1 (**arts** achievements)

TS______________________________

Detail 1______________________________

Sub-detail 1______________________________

Sub-detail 2______________________________

(Sub-detail 3) ______________________________

Detail 2______________________________

Sub-detail 1______________________________

Sub-detail 2______________________________

(Sub-detail 3) ______________________________

CS______________________________

Body Paragraph #2 (sciences achievements)

Transition/RO______________________________

Detail 1______________________________

Sub-detail 1______________________________

Sub-detail 2 ____

(Sub-detail 3) ____

Detail 2____

Sub-detail 1____

Sub-detail 2____

(Sub-detail 3) ____

CS____

Skinny Conclusion: ____

(Re-state points) ____

(1-2 sentences)

* Did you include connection/contribution to the modern world for each achievement???

Now that your research is complete and your written response well underway, it is time to work on the artistic component. Each student will complete a hexagonal design representing the achievements you wrote about in your response. Once the pieces are put together in the form of a mosaic, we'll have a beautiful way of acknowledging the work and success of the Islamic Empire.

Unlike some other religions, Islam discourages the use of human or animal pictures in art, preferring not to promote the human shape. Islamic art of the Golden Age (and today!) was created using geometric patterns, detailed designs and beautiful calligraphy. Your hexagon must demonstrate this artistic design.

Your **hexagon** must meet the following requirements:

- Artistic representation for two achievement in the <u>arts^</u>
- Artistic representation for two achievement in the <u>sciences^</u>
- Evidence of Islamic art styles
  (geometric patterns, vegetal design**, calligraphy)
- No human or animal images; no computer generated images
- Minimal use of words
- Minimum 4 colors
- Must fit within provided hexagon template (nothing over edge)

^ topics described in your written response

** vines, flowers, plants

Assessment using a 24 point combination Writing rubric and Scoring guide

Rubric and Scoring Guide for *Golden Age of Islam* Research Project

Student Name ____

	3	2	1	.5-0
Arts #1	Accurate factual **detail** supported by two or more relevant **sub details**	Accurate factual detail supported by one relevant sub detail	Accurate factual detail but no relevant sub details	Inaccurate or not present
Arts #2	Accurate factual **detail** supported by two or more relevant **sub details**	Accurate factual detail supported by one relevant sub detail	Accurate factual detail but no relevant sub details	Inaccurate or not present
Sciences #1	Accurate factual **detail** supported by two or more relevant **sub details**	Accurate factual detail supported by one relevant sub detail	Accurate factual detail but no relevant sub details	Inaccurate or not present
Sciences #2	Accurate factual **detail** supported by two or more relevant **sub details**	Accurate factual detail supported by one relevant sub detail	Accurate factual detail but no relevant sub details	Inaccurate or not present
Introduction and conclusion	**X**	Effective intro **and** effective conclusion	Adequate introduction and conclusion.	Missing introduction and/or conclusion
Connection to modern world	**X**	All four achievements thoroughly connected to modern world	All four achievements adequately connected to modern world	Some achievements thoroughly connected to modern world **OR** NO connection

____1 pt Arts achievement #1
Appropriate, accurate

____1 pt Arts achievement #2
Appropriate, accurate

____1 pt Sciences achievement #1
Appropriate, accurate

____1 pt Sciences achievement #2
Appropriate, accurate

____2 pts Colorful

____2 pts Characteristics of Islamic art

Minimum 4 colors
Little no white/bright

Vegetal or geometric patterns
No human or animal figures

_____/ 16 +   _____/ 8 = _____/ 2

Additional Helpful Resources – Prentice Hall Medieval Times to Today

History Alive! The Medieval World and Beyond

www.1001inventions.com/

www.muslimheritage.com

- http://3.bp.blogspot.com/_v36-pnY-t-A/SGCW45q5n9I/AAAAAAAAGgg/kmS80kry6pY/s1600-h/pakistan_art_08.jpg
- http://1.bp.blogspot.com/_v36-pnY-t-A/SGCW5OWCN6I/AAAAAAAAGgo/Qb67070mkoo/s1600-h/pakistan_art_09.jpg
- http://4.bp.blogspot.com/_v36-pnY-t-A/SGCXZoYDPMI/AAAAAAAAGhI/ZjHj4Dt8HHw/s1600-h/pakistan_art_03.jpg
- http://www.interamericaninstitute.org/Granada_Alhambra_Wall_Panel_94.JPG
- http://www.greatbuildings.com/cgi-bin/gbi.cgi/The_Alhambra.html/cid_2343022.html
- http://www.greatbuildings.com/cgi-bin/gbi.cgi/The_Alhambra.html/cid_2342578.html
- http://www.metmuseum.org/learn/for-educators/publications-for-educators/art-of-the-islamic-world/unit-five/chapter-one/featured-works-of-art/image-22
- http://www.greatbuildings.com/cgi-bin/gbi.cgi/Dome_of_the_Rock.html/cid_2250843.html

Stage 3 – Learning Plan

(Design learning activities to align with Stage 1 and Stage 2 expectations)

____

Key learning events needed to achieve unit goals

Lesson One

Essential Questions

What are the important physical characteristics of Arabia?

Why was Arabia a great location for trade?

The first lesson in the unit looks to identify important site and situation locations in Arabia. Located at the intersection of three continents – Africa, Asia and Europe – Arabian traders were key players in exchange of goods and ideas.

Instructional Strategy #1

Students would begin individual brainstorming, then pair-share

Where is Arabia? On what continent is it located? What bodies of water surround it? What other regions/areas are near it?

Instructional Strategy #2

Students work as partners or individuals to label physical and cultural locations in Arabia on map. Map can be found at http://www.washburn.edu/cas/history/stucker/MedMEoutlineonline.gif

Locations could include but not be limited to:

Red Sea, Mediterranean Sea, Persian Gulf, Arabian Sea,
Arabian Desert, Mecca, Medina, Baghdad, Jerusalem

Checks for Understanding: What are important site features of Arabia?
What other regions/empires are near Arabia?

Formative Assessment: What makes Arabia a great location for trade?

Sample Answers may include:

- Centrally located near Africa, Asia and Europe
- Meeting place for traders from all 3 continents
- Bordered by 3 bodies of water (Medit, Red, Persian Gulf) for ease of transportation/trade
- Close proximity to classical empires Egypt, Greece, Rome, and Persia

Assessment scored using 5 point rubric

	3	2	1	0
CLAIM	X	Clear statement that provides reason why	Statement does not provide reason why	Unclear or no statement
EVIDENCE	Specific evidence that supports claim and is explained	Evidence that supports claim but is not explained	General information, leaves reader asking "why"	Evidence does not support claim OR inaccurate information

Additional Helpful Resources – Prentice Hall Medieval Times to Today
History Alive! The Medieval World and Beyond

Lesson Two

Essential Question

What are the basic beliefs of Islam?

The second lesson in the unit focuses on the formation and spread of the Islamic religion in 600-700 CE as well as the basic beliefs and practices of Muslims today. Students can compare Islam to other major monotheistic world religions that may have been previously studied such as a Judaism and Christianity.

Instructional Strategy #1

Students engage in Scavenger Hunt for historical and theological questions about the beliefs and practice of Islam. Students can work in small groups and use various resources to find answers.

Scavenger hunt questions could include but not be limited to:

1. When a Muslim prays, he/she faces _______.
2. The Qur'an calls these people "People of the Book"
3. What is the name of a Muslim house of worship?
4. This is required of a Muslim five times a day.
5. Muslims fast in this month.
6. Complete this phrase: " Allah is the only true God and Muhammad is his _______."
7. What are five pillars of Islam?
8. The day of public prayer for Muslims is ______.
9. What are the three holiest cities for Muslims?

Muslims believe Qur'an is
A) A history of Islam or B) God's word spoken through Muhammad

Instructional Strategy #2

Teacher directed instruction reviews answers to Scavenger Hunt and outlines basic beliefs. Topics covered could include but not limited to:
Allah, Muhammad, monotheism (review), Five Pillars of Islam, Qur'an, People of Book, mosque/minaret/muezzin

Discussion could include:

- Similarities to Judaism/Christianity
  monotheism/God, holy books, prophets, share/fast/prayer, Jerusalem
- Common misconceptions/misunderstandings
  Muhammad a prophet, Qur'an God's word, Jihad as internal struggle
  People of Book, 'Peace be upon you' (Salaam Alailkum), hijab

Instructional Strategy #3 - *optional*

Students given selected readings from Teaching about Islam and Muslims in the Public School Classroom A Handbook for Educators AND/OR students view video " Arabs, Muslims and Islam" Video (available at amazon.com and School Media Associates)

Checks for Understanding:

- Why do Muslims want to learn Arabic?
- Why do some women wear hijab but others not?
- What is meaning of jihad?

Lesson Three

Essential Questions

Why did Islam spread so quickly?

The third lesson focuses on the spread of Islam and the Islamic Empire. Students will synthesize knowledge of Arabia's site and situation to understand why Islam spread so quickly within and beyond the Arabian Peninsula through a study of both primary and secondary sources.

Instructional Strategy #1

Students work in small groups/pairs to examine following documents* and complete the following organizer:

Document A
Map showing spread of Islam from 622-750
www.pinterest.com/pin/423268064954012105/

Document B
Quotes from Medieval Times to Today

"How did Islam spread so fast? One reasons was that people did not like the nearby Byzantine and Persian empires. Their rulers were harsh and oppressive." (p. 19)

"...Muhammad united the Arabs in his region into one community. Once they were working together, the became a powerful people" (p. 20)

Document C
Verses from Qur'an

"Those who submit to God and accept the true Faith; who are devout, sincere, patient, humble, charitable and chaste; who fast and are ever mindful of God – on these, both men and women, God will bestow forgiveness and rich recompense [reward]." (33:35)

".."Whoever killed a human being, except as punishment for murder or other villainy...., shall be deemed as having killed all mankind; and... whoever saved a human life shall be deemed as having saved all mankind... " (5:32)

But the believers who do good works, both men and women, shall enter Paradise." (4:124)

Document D

Quotes from The Medieval World and Beyond

"A great deal of trade passed through this region. Traders carried silk from China ad jewels, cotton and spices from India. From Africa came ivory and gold. The Romans sent glass and gold east to China... Serving as a link between such diverse regions exposed Arabia to new goods and ideas. Arabs shared their own knowledge along these trade routes." (p.76)

" Muslims introduced the Arabic language. Along with Islam, Arabic helped unite diverse people of the empire... While the Muslims did not force people to convert to Islam, some non-Arabs willingly became Muslims." (p. 90)

Document	Primary or secondary (include evidence to support)	What does each document explain about why Islam increased in popularity?
A		
B		
C		
D		

***Tier Two Vocabulary to be reviewed before / during document study:**

Oppressive, united, submit (meaning within document), diverse exposed, convert

Checks for Understanding: Which source is primary? Why?

Why were people of the region attracted to Islam? To new leadership?

Formative Assessment: Why did Islam spread so fast?

Sample Answers may include:

- Arab traders spread Islam through Africa, Asia and Europe
- Persian and Byzantine Empires disliked
- Beliefs of Islam support fair treatment and equality

- Islam united tribes of Arabia and other non Arab people

Assessment scored using 5 point rubric

	3	2	1	0
CLAIM	X	Clear statement that provides reason why	Statement does not provide reason why	Unclear or no statement
EVIDENCE	Specific evidence that supports claim and is explained	Evidence that supports claim but is not explained	General information, leaves reader asking "why"	Evidence does not support claim OR inaccurate information

Additional Helpful Resources:
daralislam.org/ Dar Al Islam Islamic Education Center Abiquiu, New Mexico
What Everyone Needs to Know About Islam by John Esposito

Differentiation

- Scavenger Hunt questions can be sorted by difficulty
- Document Study could be done in pairs/small group or as whole group
- Students could work in pairs or groups of three for the research assignment
- Artistic component of final project could be expanded or deleted as needed