Bloomfield Public Schools
Bloomfield, New Jersey 07003

Curriculum Guide

Physics CP
Grades 11-12

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Conforms to the Next Generation Science Standards and NJSLS Standards

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COURSE: CP Physics

GRADE LEVEL: 11, 12

Introduction: Most systems or processes depend at some level on physical sub-processes that occur within it, whether the system in question is a star, Earth's atmosphere, a river, or a bicycle. Understanding a process at any scale requires awareness of the interactions occurring in terms of the forces between objects, the related energy transfers, and their consequences. In this way, physics underlies natural and human created phenomena. An overarching goal for learning in physics, therefore, is to help students see that there are mechanisms of cause and effect in all systems and processes that can be understood through a common set of physical laws and principles.

Bloomfield High School's lab-based/inquiry physics course is structured so that students actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas. The learning experiences provided for students will engage them with fundamental questions about the world and how scientists have investigated and found answers to those questions. Students will have the opportunity to carry out scientific investigations and engineering design projects related to the disciplinary core ideas in physics

This curriculum is aligned with the *Next Generation Science Standards*, the *New Jersey Student Learning Standards for English Language Arts & Literacy in Science, the New Jersey Student Learning Standards for Math, and the New Jersey Core Curriculum Standards for Technology.*

This document is a tool that will provide an overview as to what to teach, when to teach it, and how to assess student progress. With considerations made for altered pacing, modifications, and accommodations; this document is to be utilized for all students enrolled in this course, regardless of ability level, native language, or classification. It is meant to be a dynamic tool that we, as educators, will revise and modify as it is used during the course of the school year.

Pacing - This CP Physics course is comprised of the following seven units:

Unit 1: Forces and Motion
Unit 2: Fundamental Forces
Unit 3: Orbital Motion
Unit 4: Energy and Momentum
Unit 5: Wave Properties and Behaviors
Unit 6: Electromagnetic Radiation
Unit 7: Electricity and Magnetism

Resources: Teachers will be able to access the curriculum document on the district website.

Textbook: Serway and Faughn, Physics, Holt Rinehart Winston

Established Goals: New Jersey Student Learning Standards
Science: **http://www.nextgenscience.org/next-generation-science-standards**
New Jersey Student Learning Standards for Math: **http://www.state.nj.us/education/cccs/2016/math/standards.pdf**
New Jersey Student Learning Standards for ELA: **http://www.state.nj.us/education/cccs/2016/ela/**
Technology: **http://www.state.nj.us/education/cccs/2014/tech/**

Modifications:

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principles (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Unit #: 1	Unit Name: Forces and Motion	Unit Length: 35

ESSENTIAL QUESTIONS:
1. How can one describe motion?
2. How can one explain and predict interactions between objects and within systems of objects?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time. *[Clarification Statement: Students should be able to accurately move from one representation of motion to another.]*	**HS-PS2-2** **HS-PS2.A**
2	Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.	**HS-PS2.A**
3	Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations.	**HS-PS2-2** **HS-PS2.A**
4	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. *[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]*	**HS-PS2-1**
5	Represent and describe the two types of forces that a surface can exert on an object - a normal force, and a friction force parallel to the surface and dependent on the normal force and textures of the two surfaces.	**HS-PS2.A**

6	Use Newton's Second Law along with the mathematical relationship among friction force and normal force to predict unknown quantities involving one-dimensional motion with constant velocity and one-dimensional motion with constant acceleration.	**HS-PS2-2** **HS-PS2.A**
7	Explain contact forces (tension, friction, normal) as arising from interatomic electric forces and their certain directions.	**HS-PS1.A**
8	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. ***[****Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]*	**HS-PS2-3**
9	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-ETS1-2**
10	Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	**HS-ETS1-3**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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. (HS-PS2-1),(HS-PS2.A) **Using Mathematics and Computational Thinking** ● Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2.A) **Constructing Explanations and Designing Solutions** ● Apply scientific ideas to solve a design problem, taking into account possible	**PS1.A: 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.A) **PS2.A: Forces and Motion** ● Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1), (HS-PS2.A) **ETS1.A: 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) **ETS1.C: Optimizing the Design Solution** ● Criteria may need to be broken down into simpler ones that can be	**Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1) ● Systems can be designed to cause a desired effect. (HS-PS2-3) **Systems and System Models** ● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) --- **Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** ● New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-3)

unanticipated effects. (HSPS2-3) ● Design a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) ● Evaluate a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)	approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to (HS-PS2-3) **ETS1.B: 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)	**Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ● Theories and laws provide explanations in science. (HS-PS2-1) ● Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1)

Connections to other DCIs in this grade-band: **HS.PS3.C** (HS-PS2-1); **HS.ESS1.A** (HS-PS2-1),(HS-PS2-2); **HS.ESS1.C** (HS-PS2-1),(HS-PS2-2); **HS.ESS2.C** (HS-PS2-1)
Articulation of DCIs across grade-bands: **MS.PS2.A** (HS-PS2-1),(HS-PS2-2),(HS-PS2-3); **MS.PS3.C** (HS-PS2-1),(HS-PS2-2),(HS-PS2-3)

New Jersey Student Learning Standards Connections:

ELA:

SL.11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on- one, in groups, and teacher-led) with peers on *grades 11–12 topics, texts, and issues,* building on others' ideas and expressing their own clearly and persuasively. (HS-PS2-1), (HS-ETS1-2)

L.11-12.6 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. (HS-PS2-1), (HS-ETS1-2)

RST.9-10.1. Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions. (HS-PS2-1)

RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)

WHST.11-12.7: 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. (HS-PS2-3)

WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1)

MATH:

MP.2: Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2)

MP.4: Model with mathematics. (HS-PS2-1),(HS-PS2-2)

HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2)

HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1),(HS-PS2-2)

HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2)

HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1)

HSA.SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS- PS2-1)

HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)

HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1),(HS-PS2-2)

HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1), (HS-PS2-2)
HSF-IF.C.7: Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. (HS-PS2-1)
HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

Technology & Career Standards:
8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.
8.1.12.A.4: Construct a spreadsheet, enter data, and use mathematical or logical functions to manipulate data, generate charts and graphs, and interpret the results.
8.2.12.D.3: Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system.

Career Ready Practices: 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Significant figures Scalar and Vector quantities Distance and Displacement Inertia Acceleration Gravitational Acceleration Force Free Body Diagram Static and Kinetic Friction Tension Normal force Newton's Laws Terminal Velocity	Analysis Components Concept Data Derive Equation Estimate Factors Function Percent Principle Procedure Range Significant Strategy Theory Variables	General laboratory equipment and measuring tools Pasco computer lab system Lab carts and tracks Force tables Bottle rocket launch pads Altimeter Variable inclined plane

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
A	Brainstorm directly measureable variables for a ball rolling down a ramp. Suggest measuring tools and techniques. Invent, apply, and critique methods for accurately measuring classroom floor area.	NA - Asking questions and defining problems. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence.
B	Utilize floor tiles to develop Position vs. Time graphs from prior lab data.	1 - Developing and using models. Analyzing and interpreting data. Obtaining, evaluating, and communicating information.
C	Atwood Machine demonstrations – predict, observe, describe, and analyze motion with balanced and unbalanced forces.	3 - Asking questions and defining problems. Developing and using models. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EXPLORE	**Examples of Exploring Activities:**	
A	Measurement lab – develop and practice measuring, data collecting, and math skills.	NA - Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information.
B	Constant Speed and Accelerated Speed lab – plan experiment to investigate linear motion, develop graphic and algebraic descriptions of motion. Pasco Motion Graphs Activity – perform physical motion to match graphic representations.	1 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information. 1 - Asking questions and defining problems. Developing and using models.

C		Planning and carrying out investigations. Engaging in argument from evidence.
	Missing Variables lab – apply speed and velocity equations to determine kinematic variables.	1 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Force Table lab – Newton's First Law, balanced forces.	2 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information.
	Newton's Second Law lab – relate force, mass, and acceleration.	2,3,4 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information.
	Friction lab – differentiate static and kinetic friction.	2,5,7 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions.

		Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EXPLAIN	**Examples of Explaining Activities:**	
A	Using a Vernier caliper. Rationale of significant figures. Applications of scientific notation. Metric conversions. Practice problem solving - significant figures, scientific notation, conversions.	NA - Using mathematics and computational thinking. Obtaining, evaluating, and communicating information.
B	Kinematic variables and equations. Scalar and vector quantities. Acceleration due to gravity. Demonstrations - gravity versus mass ball drop, vacuum cylinder. Problem solving practice – linear motion.	2,3,4 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
C	Balanced and unbalanced forces. Free Body Diagrams and vectors. Graphic organizer – Newton's Laws. Demonstrations - accelerometers, static and kinetic friction. Video – skydiving, terminal velocity. Problem solving practice – Newton's Laws and vectors.	2,3,4,5,6 - Asking questions and defining problems. Developing and using models. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence.

ELABORATE	Examples of Elaborating Activities:	
A	Constant Speed and Accelerated Speed lab – determine variables and apply measuring and data collecting skills.	NA - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Handicapped Cart Race lab – constant speed versus accelerating carts. Present and critique solutions.	1 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
C	STEM Design Project – design, construct, and field test a bottle rocket.	8,9,10 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.

EVALUATE	Examples of Evaluating Activities:	
A	Quiz – Math Skills Present, compare, critique, and correct lab methods. Lab report - Measurement	Planning and carrying out investigations. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Lab reports: Constant Speed and Accelerated Speed Missing Variables Handicapped Cart Race Test – Linear Motion	1 - Planning and carrying out investigations. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information. 1 - Using mathematics and computational thinking.
C	Lab reports - Force Table Newton's Second Law Friction STEM Project report – Bottle Rocket Test – Forces and Motion	8,9,10 - Asking questions and defining problems. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 2,3,5,6 - Using mathematics and computational thinking.

Unit #: 2	Unit Name: Fundamental Forces	Unit Length: 20

ESSENTIAL QUESTIONS:

1. How can one differentiate contact forces and field forces?
2. How can one explain and predict interactions between objects in force fields?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Develop and use a model of an object in uniform circular motion to predict and describe the relationships between centripetal force, acceleration, speed, and radius.	**HS-PS2-1**
2	Use mathematical representation of Newton's Second Law to calculate force, speed, and radius for objects undergoing uniform circular motion.	**HS-PS2-1**
3	Calculate the gravitational force two objects exert on each other in a uniform field.	**HS-PS2.B**
4	Use mathematical representations of Newton's Law of Gravitation to describe and predict the gravitational forces between objects. *[Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational fields.]* [Assessment Boundary: Assessment is limited to systems with two objects.]	**HS-PS2-4**
5	Make predictions about the sign and relative quantity of net charge of objects or systems after various charging processes.	**HS- PS2.B**
6	Construct an explanation of a model of electric charge, and make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes. *[Clarification Statement: The focus is on the mechanisms that explain conductors and insulators.]*	**HS-PS2.B**
7	Develop and use a model of two objects interacting through electric fields to illustrate the forces between objects due to the interaction. *[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]*	**HS-PS2-4**

8	Use mathematical representations of Coulomb's Law to describe and predict the electrostatic forces between objects. *[Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of electric fields.]* [Assessment Boundary: Assessment is limited to systems with two objects.*]*	**HS-PS2-4**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical representations of phenomena to describe explanations. (HS-PS2-4), (HS-PS2.B) **Developing and Using Models** • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS2-4),(HS-PS2.B)	**PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) **PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4),(HS-PS2.B) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric	**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. (HS-PS2-4) **Cause and Effect** • 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. (HS-PS2-4) **Systems and System Models** • When investigating or describing a system, the boundaries and initial

	charges or changing magnetic fields cause electric fields. (HS-PS2-4) ● Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-4)	conditions of the system need to be defined. (HS-PS2-4) - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ● Theories and laws provide explanations in science. (HS-PS2-4) Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-4)

Connections to other DCIs in this grade-band: **HS.PS2.B** (HS-ESS1-4); **HS.PS3.A** (HS-PS2-4); **HS.ESS1.A** (HS-PS2-4); **HS.ESS1.B** (HS-PS2-4); **HS.ESS1.C** (HS-PS2-4); **HS.ESS2.C** (HS-PS2-4); **HS.ESS3.A** (HS-PS2-4)
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-PS2-6); **MS.PS2.B** (HS-PS2-4),(HS-PS2-6),(HS-ESS1-4); **MS.PS2.A** (HS-ESS1-4); **MS.PS3.C** (HS-PS2-2),(HS-PS2-3); **MS.ESS1.A** (HS-ESS1-4); **MS.ESS1.B** (HS- PS2-4),(HS-ESS1-4)
New Jersey Student Learning Standards Connections: **ELA:** **SL.11-12.1** Initiate and participate effectively in a range of collaborative discussions (one-on- one, in groups, and teacher-led) with peers on *grades 11–12 topics, texts, and issues,* building on others' ideas and expressing their own clearly and persuasively.

(HS-PS2-1), (HS-PS2-4)
L.11-12.6 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. (HS-PS2-1), (HS-PS2-4)
RST.9-10.1. Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions. (HS-PS2-1),(HS-PS2-6)
RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)
WHST.11-12.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)
WHST.11-12.7: 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. (HS-PS2-3),(HS-PS2-5)
WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5)
WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1),(HS-PS2-5)

MATH:
MP.2: Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4)
MP.4: Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4)
HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2), (HS-PS2-4),(HS-PS2-5),(HS-PS2-6),(HS- ESS1-4)
HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5), (HS-PS2-6)
HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1), (HS-PS2-2),(HS-PS2-4),(HS-PS2-5),(HS-PS2-6),(HS-ESS1-4)
HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4),(HS-ESS1-4)
HSA-CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-4)

HSA-CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-4)
Technology & Career Standards: **8.1 Educational Technology:** All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge. **8.1.12.A.4:** Construct a spreadsheet, enter data, and use mathematical or logical functions to manipulate data, generate charts and graphs, and interpret the results. **Career Ready Practices:** 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Centripetal force and acceleration Newton's Law of Universal Gravitation Period Electrical charge and field Coulomb's Law Field force Electroscope Pith ball Van De Graaff generator Induced charge	Analysis Positive Components Principle Concept Procedure Data Range Derive Theory Equation Variables Estimate Factors Negative Function	General laboratory equipment and measuring tools Centripetal Force apparatus Electroscopes Plastic and glass rods; wool, fur, silk; pith balls Van De Graaff generator

THE 5 "E"s	**Examples of Learning Activities for the specified "E"**	**SLO's and Engineering Practices**
ENGAGE	**Examples of Engaging Activities:**	
A	Demonstration – Flying Pig, uniform circular motion. Video – Winter Olympics, sources of centripetal force.	1 - Asking questions and defining problems. Constructing explanations and designing solutions. Engaging in argument from evidence.
	Compare and contrast Flying Pig and planetary motion.	1 - Asking questions and defining problems.

B	Anecdote – Newton's falling apple.	Constructing explanations and designing solutions. Engaging in argument from evidence.
C	Demonstrations – Van De Graaff generator: flying plates, "lightning" Student analysis. Demonstrations – pith ball, electroscope. Student predictions.	6 - Asking questions and defining problems. Developing and using models. Constructing explanations and designing solutions. Engaging in argument from evidence.
EXPLORE	**Examples of Exploring Activities:**	
A	Centripetal Force and Acceleration lab – identify, measure, and analyze factors of uniform circular motion.	1,2 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions. Obtaining, evaluating, and communicating information.
B	Centripetal Forces in the Solar System lab – relate planetary mass, speed, and orbital radius. Universal Gravitational Constant – empirical determination using lab data and results.	3,4 - Asking questions and defining problems. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions Obtaining, evaluating, and communicating information.
C	Static Electricity lab – predict and illustrate static charge distribution and behavior.	5,6,7 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EXPLAIN	**Examples of Explaining Activities:**	
	Centripetal force, $F_c = m(v^2/r)$, in relation to Newton's	1,2 - Asking questions and defining problems.

A	Second Law. Vector analysis of centripetal acceleration. Demonstration – linear versus rotational accelerometers. Problem solving practice – uniform circular motion.	Developing and using models. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Newton's Law of Universal Gravitation in relation to Newton's Second Law. Newton's Law of Universal Gravitation as force of attraction, determination of weight, and orbital centripetal force. Problem solving practice – gravitational force.	3,4 - Asking questions and defining problems. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
C	Basic properties of electric charge. Electric and gravitational field forces. Coulomb's Law and electric charges. Electric field lines to model electric field strength and direction. Problem solving practice – electric force and field strength.	5,6,8 - Asking questions and defining problems. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
ELABORATE	**Examples of Elaborating Activities:**	
A	Guided inquiry - analyze limiting factors on flat curves and frictionless banked curves. Video – banked curves.	2 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	"Weightlessness" on the International Space Station – differentiate true weightlessness and orbital motion. Video - International Space Station.	4 - Asking questions and defining problems. Constructing explanations and designing solutions. Engaging in argument from evidence.

		Obtaining, evaluating, and communicating information.
C	Electroscope Design lab – design and construct a functioning electroscope.	7 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EVALUATE	**Examples of Evaluating Activities:**	
A	Lab report - Centripetal Force and Acceleration Quiz – Uniform Circular Motion	1,2 – Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information. 2 - Using mathematics and computational thinking.
B	Lab report - Centripetal Forces in the Solar System	3,4 - Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information.
C	Lab report - Static Electricity Lab demonstration - Electroscope Design Test - Electrostatics	5,6,7 – Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 8 - Using mathematics and computational thinking.

Unit #: 3	Unit Name: Orbital Motion	Unit Length: 20

ESSENTIAL QUESTIONS:
1. How can one describe and explain the orbital motion of planets, moons, and man-made satellites?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Develop a model to accurately represent the scales of size and distance in the Solar System.	**HS-ESS1-4**
2	Relate the period, orbital radius and speed of an object in a circular orbit, and use the model speed = 2 π R/T to predict unknown quantities. Teacher Note: Students connect this concept to Kepler's third law by replacing the mass of the earth with the mass of the sun and let R represent the radius of orbit of the planet being studied.	**HS-PS2.B**
3	Use mathematical or computational representations to predict the motion of orbiting objects in the Solar System. *[Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]*	**HS-ESS1-4**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking ● Use mathematical representations of phenomena to describe explanations. (HS-PS2.B), (HS-ESS1-4) **Developing and Using Models** ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS1-4)	**PS2.B: Types of Interactions** ● Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2.B) ● Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2.B) **ESS1.B: Earth and the Solar System** ● Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or	**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. (HS-PS2.B), (HS-ESS1-4) **Systems and System Models** ● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2.B), (HS-ESS1-4) ● - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ● Theories and laws provide explanations in science. (HS-PS2.B), (HS-ESS1-4) ● Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2.B), (HS-ESS1-4)

	collisions with, other objects in the solar system. (HS-ESS1-4)	**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). (HS-ESS1-4) -- **Connection to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and Technology** ● Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-4)

Connections to other DCIs in this grade-band: **HS.PS2.B** (HS-ESS1-4); **HS.PS3.A** (HS-PS2-4); **HS.ESS1.A** (HS-PS2-4); **HS.ESS1.B** (HS-PS2-4); **HS.ESS1.C** (HS-PS2-4); **HS.ESS2.C** (HS-PS2-4); **HS.ESS3.A** (HS-PS2-4)
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-PS2-6); **MS.PS2.B** (HS-PS2-4),(HS-PS2-6),(HS-ESS1-4); **MS.PS2.A** (HS-ESS1-4); **MS.PS3.C** (HS-PS2-2),(HS-PS2-3); **MS.ESS1.A** (HS-ESS1-4); **MS.ESS1.B** (HS- PS2-4),(HS-ESS1-4)

New Jersey Student Learning Standards Connections:

ELA:

SL.11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on- one, in groups, and teacher-led) with peers on *grades 11–12 topics, texts, and issues,* building on others' ideas and expressing their own clearly and persuasively. (HS-ESS1-4)

L.11-12.6 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. (HS-ESS1-4)

RST.9-10.1. Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions. (HS-PS2-1),(HS-PS2-6)

RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)

WHST.11-12.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)

WHST.11-12.7: 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. (HS-PS2-3),(HS-PS2-5)

WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5)

WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1),(HS-PS2-5)

MATH:

MP.2: Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4)

MP.4: Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4)

HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2), (HS-PS2-4),(HS-PS2-5),(HS-PS2-6),(HS- ESS1-4)

HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5),(HS-PS2-6) **HSN.Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5),(HS-PS2-6),(HS-ESS1-4) **HSA.SSE.A.1:** Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4),(HS-ESS1-4) **HSA-CED.A.2:** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-4) **HSA-CED.A.4:** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-4)
Technology & Career Standards: **8.1 Educational Technology:** All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge. **8.1.12.A.4:** Construct a spreadsheet, enter data, and use mathematical or logical functions to manipulate data, generate charts and graphs, and interpret the results. **Career Ready Practices:** 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Centripetal Force and Acceleration Newton's Law of Universal Gravitation Orbit Orbital Period and Radius Kepler's Laws of Planetary Motion Newton's Synthesis of Kepler's Third Law Geosynchronous Period	Analysis Components Concept Data Derive Equation Estimate Factors Ellipse Range Theory Variables Satellite Empirical Theoretical	General laboratory equipment and measuring tools Model Solar System

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Critique classroom Solar System model. Survey scientific transition from geocentrism to heliocentrism (Copernicus to Newton).	1 - Asking questions and defining problems. Engaging in argument from evidence.
EXPLORE	**Examples of Exploring Activities:**	
	Scale Model Solar System lab – compute and construct a dimensionally accurate scale model.	1 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information.
EXPLAIN	**Examples of Explaining Activities:**	
	Kepler's Laws of Planetary Motion. Demonstration – ellipse generator. Newton's synthesis of Kepler's Third Law. Problem solving practice – Kepler's Third Law and Newton's synthesis.	2,3 - Asking questions and defining problems. Using mathematics and computational thinking. Engaging in argument from evidence.
ELABORATE	**Examples of Elaborating Activities:**	
	Investigate geosynchronous, communication satellites – apply Kepler's and Newton's laws to determine orbital parameters. Planet masses – use orbiting moons data to determine masses of planets.	2,3 - Asking questions and defining problems. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions. Obtaining, evaluating, and communicating information.
EVALUATE	**Examples of Evaluating Activities:**	
	Lab report - Scale Model Solar System Test – Gravity and Orbital Motion	1 – Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Obtaining, evaluating, and communicating information. 2 - Using mathematics and computational thinking.

Unit #: 4	Unit Name: Energy and Momentum	Unit Length: 40

ESSENTIAL QUESTIONS:

1. How is energy transferred and conserved?
2. How is momentum changed and conserved?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Identify and quantify the various types of energies within a system of objects in a well-defined state, such as elastic potential energy, gravitational potential energy, kinetic energy, and thermal energy and represent how these energies may change over time.	**HS-PS3.A** **HS-PS3.B**
2	Calculate changes in kinetic energy and gravitational potential energy of a system using representations of that system.	**HS-PS3.A**
3	Construct an explanation, using atomic-scale interactions and probability, of how a closed system approaches thermal equilibrium when energy is transferred to it or from it in a thermal process	**HS-PS3.A**
4	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). *[Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]*	**HS-PS3-2**

5	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. *[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]*	**HS-PS3-1**
6	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* *[Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]*	**HS-PS3-3**
7	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. *[Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]*	**HS-PS2-2**
8	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. *[Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]*	**HS-PS2-3**
9	Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	**HS-ETS1-3**

10	Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**HS-ETS1-1**
11	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-ETS1-2**
12	Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**HS-ETS1-4**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS2-2), (HS-PS3-2) **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	**PS3.A: 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. (HS-PS3-2) ● At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2), (HS-PS3.A), (HS-PS3.B) ● These relationships are better understood at the microscopic scale,	**Cause and Effect** ● 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. (HS-PS2-3) ● Systems can be designed to cause a desired effect. (HS-PS2-3) **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

refine the design accordingly. (HS-PS2-2) **Using Mathematics and Computational Thinking** ● Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) ● Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4) **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. (HS-PS3-3) **Asking Questions and Defining Problems** ● Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)	at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2), (HS-PS3.A) **PS3.B: Conservation of Energy and Energy Transfer** ● Conservation 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) ● Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1) ● Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged	using models. (HS-PS2-2), (HS-PS2-3) ● 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. (HS-PS2-3),(HS-PS3-1) ● 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. (HS-ETS1-4) **Energy and Matter** ● 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. (HS-PS3-3) ● Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2) -

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Constructing Explanations and Designing Solutions

Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS2-2), (HS-ETS1-2)
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS2-2), (HS-ETS1-3)

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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), (HS-PS3.A)

The availability of energy limits what can occur in any system. (HS-PS3-1)

PS3.D: Energy in Chemical Processes

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)

ETS1.A: Defining and Delimiting an Engineering Problem

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-PS3-3)

ETS1.A: Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by

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Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering and Technology on Society and the Natural World

Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS2-3), (HS-PS3-3)
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1), (HS-ETS1-3)

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Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
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	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. (HS-ETS1-1) ● 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) **ETS1.B: 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) ● Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making	● Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS2-2),(HS-PS3-1)

	a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4) **ETS1.C: 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. (HS-PS2-3), (HS-ETS1-2) **PS2.A: Forces and Motion** (pp. 114-116, NRC, 2012) ● Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) ● If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3)	

Connections to other DCIs in this grade-band:

HS.PS1.A (HS-PS3-2); **HS.PS1.B** (HS-PS3-1),(HS-PS3-2); **HS.PS2.B** (HS-PS3-2); **HS.LS2.B** (HS-PS3-1); **HS.ESS1.A** (HS-PS3-1); **HS.ESS2.A** (HS-PS3-1),(HS-PS3-2);
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-PS3-2); **MS.PS2.B** (HS-PS3-2),(HS-PS3-5); **MS.PS3.A** (HS-PS3-1),(HS-PS3-2),(HS-PS3-3); **MS.PS3.B** (HS-PS3-1),(HS-PS3-3),(HS-PS3-4); **MS.PS3.C** (HS-PS3-2),(HS-PS3-5); **MS.ESS2.A** (HS-PS3-1),(HS-PS3-3)
New Jersey Student Learning Standards Connections: **ELA:** **SL.11-12.1** Initiate and participate effectively in a range of collaborative discussions (one-on- one, in groups, and teacher-led) with peers on *grades 11–12 topics, texts, and issues,* building on others' ideas and expressing their own clearly and persuasively. (HS-PS3-2), (HS-PS3-3), (HS-PS2-3) **L.11-12.6** 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. (HS-PS3-2), (HS-PS3-3), (HS-PS2-3) **RST.11-12.7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1), (HS-ETS1-3) **WHST.9-12.7:** 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. (HS-PS3-3) **SL.11-12.5:** 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. (HS-PS3-1),(HS-PS3-2) **MATH:** **MP.2:** Reason abstractly and quantitatively. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3) **MP.4:** Model with mathematics. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3) **HSN.Q.A.1:** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1),(HS-PS3-3) **HSN.Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-3) **HSN.Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1),(HS-PS3-3)
Technology & Career Standards: **8.1 Educational Technology:** All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.

8.1.12.A.4: Construct a spreadsheet, enter data, and use mathematical or logical functions to manipulate data, generate charts and graphs, and interpret the results.
8.2.12.D.3: Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system.

Career Ready Practices: 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Work Energy Power Mechanical Energy Potential and Kinetic Energy Law of Conservation of Energy Spring Constant Hooke's Law Celsius and Kelvin scales Specific Heat Capacity Heat and Thermal Energy Thermal Equilibrium Calorimeter Pendulum Conservative and Non-conservative Forces Isolated System Momentum Impulse Law of Conservation of Momentum Elastic and Inelastic Collisions	Analysis Components Concept Data Demonstrate Derive Equation Estimate Evaluation Factors Function Initial Principle Positive Procedure Source Strategy Theory Variables	General laboratory equipment and measuring tools Inclined plane Force sensors Parachute material Calorimeters Convection box Hand boilers Ball and ring Bimetal strips Lab carts and tracks Ballistic Pendulum

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
A	Class activity - brainstorm common compound words and phrases containing "work", and reason those which are physics related.	NA - Engaging in argument from evidence.
B	Demonstration - food coloring in cold and hot water beakers. Predict, observe, and analyze cold versus hot particle motion.	1 - Asking questions and defining problems. Developing and using models. Engaging in argument from evidence.
C	Newton's "Quantity of Motion" – identify relevant variables. Demonstration - ping pong ball versus solid steel ball. Analogy – basketball versus baseball.	NA - Engaging in argument from evidence.
EXPLORE	**Examples of Exploring Activities:**	
A	Work and Energy lab – investigate work and energy transformations on an inclined plane.	1,2,4,5- Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Conservation of Thermal Energy lab – investigate energy transfer in thermal equilibrium process.	1,3,4,5 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Conservation of Momentum lab – predict motion and	7 - Asking questions and defining problems.

C	investigate conservation of momentum using lab carts.	Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EXPLAIN	**Examples of Explaining Activities:**	
A	Work as a function of force and distance. Seven types of energy. Potential and kinetic forms of energy. Law of Conservation of Energy in ideal and actual processes. Conservative forces: gravity, electric, magnetic, elastic. Hooke's Law and elastic potential energy formula. Conservative and non-conservative forces as related to energy transformations. Power in relation to work and energy transfer. Demonstrations - pendulum, bounce versus no-bounce balls, loop the loop. Class activities – graphical derivation of spring constant, power pulley hoist. Practice problem solving – work, energy, and power.	1,2,4,5 - Asking questions and defining problems. Developing and using models. Using mathematics and computational thinking. Engaging in argument from evidence.
B	Temperature and temperature scales. Relationships between temperature, thermal energy, and heat. Calorimeter design. Law of Conservation of Energy in thermodynamic processes. Activity – Temperature vs. Time graph for ice water through boiling. Practice problem solving – heat transfer.	1,3,4,5 - Asking questions and defining problems. Developing and using models. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence.

C	Impulse and momentum in terms of Newton's 2nd law. Impulse - Momentum theorem. Law of Conservation of Momentum as applied to isolated systems. Elastic & inelastic events. Demonstrations – steel and clay pendula, egg toss. Practice problem solving – impulse and momentum.	7,8 - Asking questions and defining problems. Developing and using models. Using mathematics and computational thinking. Engaging in argument from evidence.
ELABORATE	**Examples of Elaborating Activities:**	
A	STEM Design Project, Model Parachute – apply concepts of work and energy to maximize drop time and minimize landing impulse. Research Project, Alternative Energy – present physics analysis and pros and cons of alternative energy production (hydroelectric, wind, geothermal, tidal).	1,2,4,5,6,8,11,12 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 1,4,9,10 - Asking questions and defining problems. Planning and carrying out investigations. Analyzing and interpreting data. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Heat and Thermal Expansion stations activity – observe, analyze, and explain examples of thermal expansion processes in solids, liquids, and gasses (hand "boiler", convection box, water chimney, density ball, unscaled "thermometer", ball and ring, bimetal strips).	1,4 - Asking questions and defining problems. Developing and using models. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.

C	Ballistic Pendulum lab – analyze operation by applying principles of Newton's laws, work, energy, power, and momentum.	7 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EVALUATE	**Examples of Evaluating Activities:**	
A	Lab report – Work and energy STEM Design Project - Model Parachute Research Project - Alternative Energy Test – Work, Energy, Power	1,2,4,5 – Planning and carrying out investigations. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 1,2,4,5,6,8,11,12 – Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 1,4,9,10 - Asking questions and defining problems. Planning and carrying out investigations. Analyzing and interpreting data. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 1,2,5 - Using mathematics and computational thinking.

B	Lab report - Conservation of Thermal Energy Activity report - Heat and Thermal Expansion Quiz – Thermal Energy and Heat	1,3,5 – Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 1,4 – Planning and carrying out investigations. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 3,5 - Using mathematics and computational thinking.
C	Lab reports - Conservation of Momentum Ballistic Pendulum Test – Impulse and Momentum	7 – Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 7 – Using mathematics and computational thinking.

Unit #: 5	Unit Name: Wave Properties and Behaviors	Unit Length: 20

ESSENTIAL QUESTIONS:

1. How do waves transfer energy?
2. How does wave behavior describe natural phenomena in the universe?
3. How can the knowledge of wave behavior help us generate new technologies?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. *[Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]*	**HS-PS4-1**
2	Use mechanical models to investigate basic wave properties and behaviors.	**HS-PS4.A**
3	Create an experiment to establish the correlation between frequency, wavelength, and wave speed.	**HS-PS4.A**
4	Use ray diagrams to graphically locate and describe images produced by plane mirrors and to confirm the Law of Reflection.	NA
5	Devise a method which graphically traces a light ray travelling from a faster medium into a slower medium, and vice versa, and which quantifiably confirms Snell's Law.	NA
6	Observe and analyze a variety of phenomena that are explained by the wave nature of light, such as reflection, refraction, diffraction, polarization, and interference.	NA
7	Design and carry out experiments to determine which variables affect the periods of a pendulum and a mass-spring system in simple harmonic motion.	NA

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking ● Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1) **Developing and Using Models** ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS4.A)	**PS4.A: Wave Properties** ● The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4.A) ● [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4.A)	**Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4.A) **Systems and System Models** ● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS4.A)

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS1-2); **HS.PS1.C** (HS-PS4-4),(HS-ESS1-2); **HS.PS3.A** (HS-PS4-4),(HS-PS4-5),(HS-ESS1-2); **HS.PS3.B** (HS-ESS1-2); **HS.PS3.D** (HS-PS4-3),(HS-PS4-4); **HS.PS4.A** (HS-ESS1-2); **HS.LS1.C** (HS-PS4-4); **HS.ESS1.A** (HS-PS4-3); **HS.ESS2.A** (HS-PS4-1); **HS.ESS2.D** (HS-PS4-3)
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS1-2); **MS.PS3.D** (HS-PS4-4); **MS.PS4.A** (HS-PS4-1),(HS-PS4-2),(HS-PS4-5); **MS.PS4.B** (HS-PS4-1),(HS-PS4-2),(HS-PS4-3),(HS-PS4-4),(HS-PS4-5,(HS-ESS1-2); **MS.PS4.C** (HS-PS4-2),(HS-PS4-5); **MS.LS1.C** (HS-PS4-4); **MS.ESS1.A** (HS-ESS1-2); **MS.ESS2.D** (HS-PS4-4)

New Jersey Student Learning Standards Connections:

ELA:
SL.11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on- one, in groups, and teacher-led) with peers on *grades 11–12 topics, texts, and issues,* building on others' ideas and expressing their own clearly and persuasively. **(**HS-PS4.A)
L.11-12.6 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. **(**HS-PS4.A)
RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1)
RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-1)

MATH:
MP.2: Reason abstractly and quantitatively. (HS-PS4-1)
MP.4: Model with mathematics. (HS-PS4-1)
HSA-SSE.A.1: Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1)
HSA-SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1)
HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1)
HSN-Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-2)
HSN-Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS4-1)
HSN-Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS4-1)

Technology & Career Standards:
8.1.12.A.4: Construct a spreadsheet, enter data, and use mathematical or logical functions to manipulate data, generate charts and graphs, and interpret the results.

Career Ready Practices: 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Mechanical and non-mechanical waves Transverse and longitudinal waves Crest and Trough Compression and Rarefaction Wavelength Frequency and Period Amplitude Intensity Constructive and destructive interference Standing waves Doppler Effect Resonance Medium Law of Reflection Plane mirror Ray diagram Concave and Convex Lenses Focal Point Refraction and Snell's Law Total Internal Reflection Diffraction Young's double slit experiment Spectrum tube Primary colors	Analysis Theory Assessment Variables Benefit Source Components Significant Concept Relevant Criteria Research Data Equation Estimate Evaluation Factors Function Principle Procedure Range Diverge and Converge Additive and Subtractive	General laboratory equipment and measuring tools Slinkies Tuning forks Assorted springs Plane and curved mirrors Refraction glass Prisms and lenses Polarizing filters Color filters Light box Color wheel Diffraction gratings Spectrum tubes and power supplies

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
A	Demonstrations - transfer of energy through a rope by a transverse wave, transverse and longitudinal waves in a slinky. Develop list of observable and measureable properties and behaviors.	1 - Asking questions and defining problems. Developing and using models. Engaging in argument from evidence.
B	Demonstrate wave nature of light - hit "START"button, regular and diffuse reflection, refracted ruler, prism spectrum, polarizers and glare.	6 - Asking questions and defining problems. Developing and using models. Engaging in argument from evidence.
EXPLORE	**Examples of Exploring Activities:**	
A	Mechanical Waves lab – produce, observe, measure, illustrate, and analyze wave properties and behaviors in a slinky.	1,2,3 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Plane Mirror Reflection lab – graphically locate virtual image. Refraction lab – graphically trace light ray into and out of glass.	4,6 – Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.

EXPLAIN	Examples of Explaining Activities:	
A	Mechanical waves – transverse and longitudinal. Graphic organizer – wave properties, variables, units. Wave behaviors from lab observations. Medium and wave speed. Interference phenomena. Intensity versus loudness. Sound and harmonics in tubes and strings. Doppler Effect. Activity – tuning forks and meter sticks. Demonstrations - bell jar doorbell, beats, string harmonics, organ pipes. Video – Galloping Gertie. Problem solving practice – frequency, period, wavelength, speed, intensity, harmonics.	1,2,3 - Asking questions and defining problems. Developing and using models. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Wave nature of light. Color addition, subtraction, and dispersion. Reflection, refraction, and polarization. Interference phenomena and Young's double slit experiment. Ray diagrams and optics. Demonstrations - color filters, light box, color wheel, refraction tank, total internal reflection, Young's model. Activities - colors through color filters, convex and concave mirrors and lenses, diffraction gratings. Problem solving practice – Law of Reflection and Snell's Law.	1,2,4,5,6 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.

ELABORATE	Examples of Elaborating Activities:	
A	Speed of Sound in Air lab – standing waves in air in open and closed tubes. Stem Design Project – design, construct, and demonstrate a musical instrument. Simple Harmonic Motion activity - design and carry out experiments to determine which variables affect the periods of a pendulum and a mass-spring system in simple harmonic motion.	1,2,3 – Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 1,2,3 - Asking questions and defining problems. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Obtaining, evaluating, and communicating information. 7 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
B	Wavelengths of Light lab – geometrically determine wavelengths of colors seen through a diffraction grating.	2,6 - Asking questions and defining problems. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.

EVALUATE	Examples of Evaluating Activities:	
A	Lab reports - Mechanical Waves Speed of Sound in Air	1,2,3 – Asking questions and defining problems. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Stem Design Project – Musical Instrument	1,2,3 – Asking questions and defining problems. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions.
	Activity report – Simple Harmonic Motion	7 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Test – Mechanical Waves and Sound	1 – Using mathematics and computational thinking.
B	Lab reports: Plane Mirror Reflection Refraction Wavelengths of Light	2, 4 – Planning and carrying out investigations. Analyzing and interpreting data. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Quiz – Visible Light	1,6 - Using mathematics and computational thinking.

Unit #: 6	Unit Name: Electromagnetic Radiation	Unit Length: 15

ESSENTIAL QUESTIONS:
1. How can the knowledge of wave behavior help us generate new technologies?
2. How does naturally occurring and technologically produced electromagnetic radiation impact our lives?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. *[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]*	**HS-PS4-4**
2	Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. *[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory calculations.]*	**HS-PS4-3**
3	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.* *[Clarification Statement: Examples could include solar cells*	**HS-PS4-5**

	capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*]*	
4	Evaluate questions about the advantages of using a digital transmission and storage of information. *[Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]*	**HS-PS4-2**
5	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	**HS-ETS1-1**
6	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-ETS1-3**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3) **Obtaining, Evaluating, and Communicating Information** • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports,	**PS4.A: Wave Properties** • Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3)	**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. (HS-PS4-3) **Cause and Effect** • Cause and effect relationships can be suggested and predicted for complex

verifying the data when possible. (HS-PS4-4) • Communicate 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 (including orally, graphically, textually, and mathematically). (HS-PS4-5) **Asking Questions and Defining Problems** • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) • Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2) **Constructing Explanations and Designing Solutions** • Evaluate a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)	• Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-5) • Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2) **PS4.B: Electromagnetic Radiation** • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)	natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4) • Systems can be designed to cause a desired effect. (HS-PS4-5) **Stability and Change** • Systems can be designed for greater or lesser stability. (HS-PS4-2) **Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5) **Influence of Engineering, Technology, and Science on Society and the Natural World** • Modern civilization depends on major technological systems. (HS-PS4-5), (HS-PS4-2) • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-3) • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits

	• Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5) **PS3.D: Energy in Chemical Processes** • Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary to HS-PS4-5) **PS4.C: Information Technologies and Instrumentation** • Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5) **ETS1.A: 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	while decreasing costs and risks. (HSPS4-2) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ● A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)

	way that one can tell if a given design meets them. (HS-ETS1-1) • 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) **ETS1.B: 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)	

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS1-2); **HS.PS1.C** (HS-PS4-4),(HS-ESS1-2); **HS.PS3.A** (HS-PS4-4),(HS-PS4-5),(HS-ESS1-2); **HS.PS3.B** (HS-ESS1-2); **HS.PS3.D** (HS-PS4-3),(HS-PS4-4); **HS.PS4.A** (HS-ESS1-2); **HS.LS1.C** (HS-PS4-4); **HS.ESS1.A** (HS-PS4-3); **HS.ESS2.A** (HS-PS4-1); **HS.ESS2.D** (HS-PS4-3)
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS1-2); **MS.PS3.D** (HS-PS4-4); **MS.PS4.A** (HS-PS4-1),(HS-PS4-2),(HS-PS4-5); **MS.PS4.B** (HS-PS4-1),(HS-PS4-2),(HS-PS4-3),(HS-PS4-4),(HS-PS4-5,(HS-ESS1-2); **MS.PS4.C** (HS-PS4-2),(HS-PS4-5); **MS.LS1.C** (HS-PS4-4); **MS.ESS1.A** (HS-ESS1-2); **MS.ESS2.D** (HS-PS4-4)
New Jersey Student Learning Standards Connections: **ELA:**

SL.11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on- one, in groups, and teacher-led) with peers on *grades 11–12 topics, texts, and issues,* building on others' ideas and expressing their own clearly and persuasively. (HS-PS4-4), (HS-PS4-5)
L.11-12.6 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. (HS-PS4-4), (HS-PS4-5)
RST.9-10.8: Determine if the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)
RST.9-10.1. Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4),(HS-ESS1-2)
RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1),(HS-PS4-4)
RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)
WHST.9-12.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS- PS4-5),(HS-ESS1-2)
WHST.11-12.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4)

MATH:
MP.2: Reason abstractly and quantitatively. (HS-PS4-1),(HS-PS4-3), (HS-ESS1-2)
MP.4: Model with mathematics. (HS-PS4-1)
HSA-SSE.A.1: Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1),(HS-PS4-3),(HS-ESS1-2)
HSA-SSE.B.3: Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1),(HS-PS4-3)
HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1),(HS-PS4-3),(HS-ESS1-2)
HSN-Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-2)
HSN-Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-2)

HSN-Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-2) **HSA-CED.A.2:** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-2)
Technology & Career Standards: **8.1 Educational Technology:** All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge. **8.2.12.A.2:** Analyze a current technology and the resources used, to identify the trade-offs in terms of availability, cost, desirability and waste. **8.2.12.B.4:** Investigate a technology used in a given period of history, e.g., stone age, industrial revolution or information age, and identify their impact and how they may have changed to meet human needs and wants. **Career Ready Practices:** 1-12

Unit Plan			
Content Vocabulary	**Academic Vocabulary**		**Required Resources**
Non-mechanical Waves Frequency and Wavelength Intensity Electromagnetic radiation Electromagnetic waves: Radio, Micro, Infrared, Visible Light, Ultraviolet, X-rays, Gamma Rays. Photon Photoelectric Effect Quantum energy Fiber Optics Electron	Analysis Assessment Benefit Components Concept Criteria Data Equation Estimate Evaluate Factors Function	Theory Variables Source Significant Relevant Research Region Range Procedure Principle	General laboratory equipment and measuring tools Optical fiber

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Examples and demonstrations of technological change – copper wire versus optical fiber, phonograph record and turntable versus CD and laser reader, land line telephone connection versus cellphone.	3 - Constructing explanations and designing solutions. Engaging in argument from evidence.
EXPLORE	**Examples of Exploring Activities:**	
	Electromagnetic Radiation research project – research and report on historical, natural, phenomenological, technological, and harmful effects of segments of the electromagnetic spectrum.	1,3,4 - Asking questions and defining problems. Planning and carrying out investigations. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EXPLAIN	**Examples of Explaining Activities:**	
	Survey electromagnetic spectrum. Transverse wave model of electromagnetic radiation. E-M waves and energy transformations. Development of atomic theory. Quantum energy and the particle theory of E-M radiation.	1,2,3 - Asking questions and defining problems. Using mathematics and computational thinking. Engaging in argument from evidence.
ELABORATE	**Examples of Elaborating Activities:**	
	Class debate – pros and cons of storage and transmission of digital information regarding cost, convenience, control, availability, universality, privacy, social media, societal mores, safety, solutions, etc.	3,4,5,6 - Asking questions and defining problems. Planning and carrying out investigations. Analyzing and interpreting data. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EVALUATE	**Examples of Evaluating Activities:**	
	Electromagnetic Radiation research project Class debate	1,3,4 – Asking questions and defining problems. Planning and carrying out investigations. Engaging in argument from evidence. Obtaining, evaluating, and communicating information. 3,4,5,6 - Asking questions and defining problems.

		Planning and carrying out investigations. Analyzing and interpreting data. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.

Unit #: 7	Unit Name: Electricity and Magnetism	Unit Length: 15

ESSENTIAL QUESTIONS:
1. How do charges interact with electric and magnetic fields?
2. How do electrical devices produce energy transformations?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. *[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]*	**HS-PS3-5**
2	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. *[Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]*	**HS-PS2-5**
3	Plan and conduct an investigation that supports the relationship between voltage, resistance and current as described in Ohm's Law.	NA
4	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* *[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]* *[Teacher Note: The emphasis in this unit is on the electrical properties of materials.]*	**HS-PS2-6**
5	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* *[Clarification Statement: Emphasis is on both*	

	qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]	**HS-PS3-3**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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. (HS-PS2-5) **Developing and Using Models** • Develop and use a model based on evidence to illustrate the relationships between systems or between	**PS2.B: Types of Interactions** • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-5) • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6) • **PS3.C: Relationship between Energy and Forces** • When two objects interacting through a field change relative position, the	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-5) • 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. (HS-PS3-5) **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 of a system. (HS-PS2-5), (HS-PS3-5) **Obtaining, Evaluating, and Communicating Information** ● Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6,3-3)	energy stored in the field is changed. (HS-PS3-5) **PS3.A: Definitions of Energy** ● "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. *(secondary to HS-PS2-5)*	components to reveal its function and/or solve a problem. (HS-PS2-6)

Connections to other DCIs in this grade-band: **HS.PS2.B** (HS-PS3-5); **HS.PS3.A** (HS-PS2-4),(HS-PS2-5); **HS.PS4.B** (HS-PS2-5); **HS.ESS1.A** (HS-PS2-4); **HS.ESS1.B** (HS-PS2-4); **HS.ESS1.C** (HS-PS2-4); **HS.ESS2.A** (HS-PS2-5); **HS.ESS2.C** (HS-PS2-4); **HS.ESS3.A** (HS-PS2-4),(HS-PS2-5)
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-PS2-6); **MS.PS2.B** (HS-PS2-4),(HS-PS2-5),(HS-PS2-6),(HS-PS3-5); **MS.PS3.C** (HS-PS3-5); **MS.ESS1.B** (HS-PS2-4),(HS-PS2-5)
New Jersey Student Learning Standards Connections: **ELA:** **SL.11-12.1** Initiate and participate effectively in a range of collaborative discussions (one-on- one, in groups, and teacher-led) with peers on *grades 11–12 topics, texts, and issues,* building on others' ideas and expressing their own clearly and persuasively (HS-PS3-5), (HS-PS3-3) **L.11-12.6** 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. (HS-PS3-5), (HS-PS3-3)

RST.9-10.1. Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions. (HS-PS2-6) **WHST.11-12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS- PS2-6) **WHST.11-12.7:** 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. (HS-PS2-5), (HS-PS3-5) **WHST.11-12.8:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5), (HS-PS3-5) **WHST.9-12.9:** Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-5),(HS-PS3-5) **SL.11-12.5:** 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. (HS-PS3-5) **MATH:** **MP.2:** Reason abstractly and quantitatively. (HS-PS2-4),(HS-PS3-5) **MP.4:** Model with mathematics. (HS-PS2-5),(HS-PS3-5) **HSN.Q.A.1:** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-5),(HS-PS2-6) **HSN.Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-5),(HS-PS2-6) **HSN.Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-5),(HS-PS2-6) **HSA.SSE.B.3:** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-5) **HSA.CED.A.1:** Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-5)
Technology & Career Standards: **8.1 Educational Technology:** All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge. **8.1.12.A.4:** Construct a spreadsheet, enter data, and use mathematical or logical functions to manipulate data, generate charts and graphs, and interpret the results. **8.2.12.D.3:** Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system.

Career Ready Practices: 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Conductor Insulator Semiconductor Induction Ground Magnetic field Electromagnetism Electromagnetic induction Electric current and Ampere Electric circuit Electric potential and Voltage Resistance Ohm's Law Capacitance Photoelectric cell Electric motor Electric generator Direct Current and Alternating Current Kirchhoff's Loop and Junction Rules Lenz's Law Voltmeter, Ammeter, Galvanometer	Attraction Repulsion Analysis Components Concept Data Demonstrate Equation Elements Estimate Factors Function Positive Principle Procedure Range Resource Utilize Series Significant Source Strategy Theory Variables Parallel	General laboratory equipment and measuring tools Voltmeters Ammeters Galvanometers Variable power source Inductance coils Wires, connectors, and switches Assorted resistors and bulbs Doorbells and buzzers Photoelectric cells Bar magnets Hand generators Compasses DC motors Potato clock Fan carts

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Small group and class activity – identify and explain use of assorted, common, electric circuit components.	NA - Asking questions and defining problems. Engaging in argument from evidence.
EXPLORE	**Examples of Exploring Activities:**	
	Magnetism and Electricity lab – use compasses to reveal magnetic field lines of a bar magnet and a current carrying coil, use galvanometer to indicate induced current in a coil within a moving magnetic field.	1,2 – Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Series and Parallel Circuits lab – design and build simple bulb circuits, identify and measure necessary variables to verify Ohm's Law and Kirchhoff's Rules	3,5 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Electric Generators and Motors activity – analyze and explain how generators and motors function in terms of electromagnetic principles.	1,2 - Asking questions and defining problems. Planning and carrying out investigations. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EXPLAIN	**Examples of Explaining Activities:**	
	Conductors and insulators. Magnetic force and fields. Electromagnetic induction. Resistance and Ohm's Law. Series and parallel resistors. Simple circuits and Kirchhoff's Rules. Electric potential and capacitance. Electric generators and motors.	1,2,3,4 - Asking questions and defining problems. Developing and using models. Using mathematics and computational thinking. Engaging in argument from evidence.

	Demonstrations: series and parallel bulb circuits, charge and discharge a capacitor. Problem solving practice – equivalent resistance and Ohm's Law.	
ELABORATE	**Examples of Elaborating Activities:**	
	Demonstrate and explain circuits and/or devices that utilize at least two energy conversions.	1,2,5 - Asking questions and defining problems. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
EVALUATE	**Examples of Evaluating Activities:**	
	Lab reports - Magnetism and Electricity	1,2 – Planning and carrying out investigations. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Series and Parallel Circuits	5 – Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Using mathematics and computational thinking. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Small group presentations – Energy Conversions	1,2,5 - Asking questions and defining problems. Developing and using models. Planning and carrying out investigations. Constructing explanations and designing solutions. Engaging in argument from evidence. Obtaining, evaluating, and communicating information.
	Test – Magnetism and Electricity	3 - Using mathematics and computational thinking.