Bloomfield Public Schools
Bloomfield, New Jersey 07003

Curriculum Guide

AP Physics C
Grade 12

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Conforms to the Next Generation Science Standards and the NJSLS Standards

Board Approved: September 12, 2017

AP Physics C
GRADE LEVEL: 12

Introduction: Students in the State of New Jersey and enrolled in Bloomfield High School must successfully complete three year-long science courses in order to meet the state mandated requirements for graduation. *AP Physics C is* available to 12th grade students who have successfully completed AP Physics 1 and Pre-Calculus/Pre-Calculus Honors. Students are expected to take the AP Physics C Exam.

AP Physics C is a course that utilizes an application of mathematics to problem solve in the physical world. This is a calculus based course, covering mechanics, electricity, and magnetism. Differential and Integral calculus are utilized in problem solving. Teacher demonstrations and laboratory exercises are essential pedagogical components for understanding fundamental concepts.

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. As well, 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:

Unit 1: Force and Motion
Unit 2: Work/Energy and Gravity
Unit 3: Rotational Dynamics (w/ Simple Harmonic Motion)
Unit 4: Electric Field & Gauss
Unit 5: Electric Circuits
Unit 6: Electromagnetism

Resources: Electronic and text resources are listed in each unit. Teachers will be able to access the curriculum document on the district website.

Textbook: AP Physics, Holt: 2002

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 principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Unit #: 1	Unit Name: Force and Motion	Unit Length: 4 Weeks

ESSENTIAL QUESTIONS:

What are the causal models of motion and how are they used?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.	HS-PS2.-1
2	Patterns of Straight-Line Motion Students understand that there are different patterns of straight-line motion that can be represented using different models.	Standard PS.1 Objective PS.1.1
3	Forces and Motion Students understand that when the sum of the forces is equal to zero, either the object is not moving and it will continue to not move, or the object is moving and it will always continue to move at a constant speed in a straight line (Newton's first law).	Objective PS.1.2
4	Interactions and Forces Students understand that interactions can be described in terms of forces. These interactions occur when two objects in contact push or pull on each other, which can cause a change in motion of one or both objects.	Objective PS.1.3
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

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 Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4), (HS-PS1-8) • Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1) **Planning and Carrying Out Investigations** Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to	**PS2.B: Types of Interactions** • 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. *(secondary to HS-PS1-1),(secondary to HS-PS1-3)*	**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-PS1-1),(HS-PS1-2),(HS-PS1-3),(HS-PS1-5) *Connections to Nature of Science* **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent.

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), **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.		

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. ● Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2)		

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)

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)

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)

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-ETS1-1)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1)

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)

MP.4	Model with mathematics. (HS-PS2-1)
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-PS2-1)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1)
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)
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)
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1)
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.

Career Ready Practices: 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Velocity Scalar Acceleration Dimensional motion Force Vector Reference frame Friction Components Equilibrium	Analysis Area Concept Data Function Evaluate Prediction Comparison Relative Magnitude	Computer Computer Interface (Pasco or other) Solid uniform carts Inclines

THE 5 “E”s	Examples of Learning Activities for the specified “E”	SLO’s and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Video 1 & 2 Dimensional Motion	1, 4 Asking Questions and Defining Problems
	Discussion What is Motion?	1, 4 Asking Questions and Defining Problems
	Racing car Activity (Observe and record linear speeds)	1 ,2 Developing and Using Models
	Force and Motion Activity (How are the force and motion related?)	1,4 Asking Questions and Defining Problems
EXPLORE	**Examples of Exploring Activities:**	
	1 Dimensional Motion Lab (Observe & record stops, starts, accelerations)	1, 2, 3, 4 Asking Questions and Defining Problems
	Projectile Lab (Qualify and quantify linear and vertical displacements)	1, 2, 3 Developing and Using Models Using Mathematics and Computational Thinking
	Force and Motion Lab (record and compare and predict motions)	1, 3, 4 Developing and Using Models Planning and Carrying Out Investigations Using Mathematics and Computational Thinking

EXPLAIN	Examples of Explaining Activities:	
	Student Analysis of Labs (What did student do qualitatively and quantitatively)	1, ,2, 3, 4, 5 Asking Questions and Defining Problems Planning and Carrying Out Investigations Analyzing and Interpreting Data Using Mathematics and Computational Thinking Obtaining, Evaluating, and Communicating Information
	Results and theory comparisons	1,2, 3, 4, 5 Developing and Using Models Analyzing and Interpreting Data Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information 2, 3, 4 Obtaining, Evaluating, and Communicating Information
	Calculation of actual values	1, 3, 4 Analyzing and Interpreting Data Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions

ELABORATE	Examples of Elaborating Activities:	
	Full Quantitative permutations (Documenting all linear and vertical motions and evaluating data)	1, 2, 3, 4, 5 Planning and Carrying Out Investigations Analyzing and Interpreting Data Engaging in Argument from Evidence Using Mathematics and Computational Thinking Obtaining, Evaluating, and Communicating Information
	Distinction of theoretical to experimental values (comparison of student results to what it should be)	1, 2, ,3, 4, 5 Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information
	Compare and Contrast calculation answers (What accounts for differences?)	1, 2, 3, 4, 5 Analyzing and Interpreting Data Using Mathematics and Computational Thinking Obtaining, Evaluating, and Communicating Information

EVALUATE	Examples of Evaluating Activities:	
	Self-Evaluation of planned ideas and hypothesis	1, 2, 3, 4, 5 Analyzing and Interpreting Data Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information Obtaining, Evaluating, and Communicating Information
	Quantitative and qualitative assessments (Student assess their needs, understandings, results)	1, 2, 3, 4, 5 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

Unit #: 2	Unit Name: Work/ Energy and Gravity	Unit Length: 4 wks

ESSENTIAL QUESTIONS:

How we Use and Evaluate the Cycle of Energy on a Global Scale?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	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 positions of particles (objects).	HS-PS3-2
2	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
3	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.	HS-PS2-2
4	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between 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
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS-PS3-5) **Planning and Carrying Out Investigations** Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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	**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-PS3-1),(HS-PS3-2) • These relationships are better understood at the microscopic scale, 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	**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-PS3-5) **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4) • 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-PS3-1)

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-PS3-4) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)	concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)	**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)

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.		

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)

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)

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-PS3-4)

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),(HS-PS3-4),(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-PS3-4),(HS-PS3-5)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4),(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-PS3-1),(HS-PS3-2),(HS-PS3-5)
Math:	
MP.2	Reason abstractly and quantitatively. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(HS-PS3-5)
MP.4	Model with mathematics. (HS-PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(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-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. **Career Ready Practices:** 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Potential Energy Kinetic Energy Gravity Power Momentum Conservative Force Conservation	Analysis Area Prediction Integration Derivative Function Vector Scalar	Computer Blocks with Inclines Force sensor interface program Circular tracks

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Video: Circular Motion and Gravity (What is it and how does it happen?)	1 Asking Questions and Defining Problems
	Demonstration: Conservation of Energy/Momentum (Observe and try to predict the outcome)	1 Asking Questions and Defining Problems Developing and Using Models
	Lasso – Circular Motion Activity (What is the relation between circular force and speed?)	1, 2, 4 Asking Questions and Defining Problems Developing and Using Models
EXPLORE	**Examples of Exploring Activities:**	
	Centripetal Force Lab (measure actual values of what is takes to maintain a moving circular force)	2,4 Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data
	Tangential Force/Velocity Activity (How far does ball go after you let it go?)	2, 3, 4 Asking Questions and Defining Problems Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data
	Video: What is Gravity and Energy? (How is the relative potential energy of a satellite measured?)	1, 2 Asking Questions and Defining Problems Developing and Using Models
EXPLAIN	**Examples of Explaining Activities:**	

	Teacher and student lab analysis of lab (How are scalar and vector results predicted?)	2, 3, 4 Analyzing and Interpreting Data Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions
	Experimental Results Comparisons (How do group results compare and why)	2, 3, 4 Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information
ELABORATE	**Examples of Elaborating Activities:**	
	Prediction and Theoretical Values reviewed and explained	1, 2, 3, 4, 5 Using Mathematics and Computational Thinking Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information
	Mini lecture on Change in Energy Values and Gravity	1, 2 Engaging in Argument from Evidence
EVALUATE	**Examples of Evaluating Activities:**	
	Compare and Contrast all Quantitative Results	2, 4 Analyzing and Interpreting Data Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions Engaging in Argument from Evidence

	Student self-evaluation of progress	2, 3, 4 Using Mathematics and Computational Thinking Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information

Unit #: 3	Unit Name: Rotational Dynamics (wi/ Simple Harmonic Motion)	Unit Length: 3 wks

ESSENTIAL QUESTIONS:
How can we harness the linear and rotational dynamics of items and life in nature to develop a more productive and safer planet?

#	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 mediums.	HS-PS4-1
2	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

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
Asking Questions and Defining Problems Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • 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)	**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.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-PS4-1)	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1) • 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-PS4-4)

Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and	• 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),(HS-PS4-5) • [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-PS4-3) **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	• Systems can be designed to cause a desired effect. (HS-PS4-5) **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) **Stability and Change** • Systems can be designed for greater or lesser stability. (HS-PS4-2) - ***Connections to Engineering, Technology, and Applications of Science***

reliability of the claims, methods, and designs. • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, 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)	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) • Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (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-PS4-1).	**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-PS4-2),(HS-PS4-5) • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS4-2) ***Connections to Nature of Science*** **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 and 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)

New Jersey Student Learning Standards Connections:

ELA:

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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-ETS1-1)
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (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)
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)
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)
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)
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)

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. **Career Ready Practices:** 1-12

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Angular Rotation Rotational Kinetic Energy Moment of Inertia Torque Angular Momentum Vector product	Calculation Analysis Summation Integration Derivation Prediction	Blocks of uniform density Line or cord Motion sensors for computer interface Cylinder samples with different moments of inertia

THE 5 "E"s	**Examples of Learning Activities for the specified "E"**	**SLO's and Engineering Practices**
ENGAGE	**Examples of Engaging Activities:**	
	Video (Rotation vs Linear)	1 Asking Questions and Defining Problems
	Demonstration (Rotational disk)	1
	Discussion (How do angular and linear differ?)	1 Asking Questions and Defining Problems

EXPLORE	Examples of Exploring Activities:	
	Rotational Lab (Measuring speeds and displacements by moments of inertia)	1 Asking Questions and Defining Problems Developing and Using Models
	Spinning tops Activity (What accounts for Precession and angular momentum?)	1 Asking Questions and Defining Problems
EXPLAIN	**Examples of Explaining Activities:**	
	Break out Student lab analysis (How do student lab measurements differ?)	1 Asking Questions and Defining Problems Developing and Using Models Analyzing and Interpreting Data
	Lab and Prediction data compared (What should results be?)	Planning and Carrying Out Investigations Analyzing and Interpreting Data Using Mathematics and Computational Thinking
ELABORATE	**Examples of Elaborating Activities:**	
	Quantitative calculations (of lab and theoretical analysis)	Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data Using Mathematics and Computational Thinking – Constructing Explanations and Designing Solutions

	Qualitative Descriptions (how do sketches of angular momentum differ?)	Developing and Using Models Planning and Carrying Out Investigations – Constructing Explanations and Designing Solutions Engaging in Argument from Evidence
EVALUATE	**Examples of Evaluating Activities:**	
	Self-Evaluation of comparative Moment of Inertia and Kinetic energy calculations	1, 2 Using Mathematics and Computational Thinking – Constructing Explanations and Designing Solutions
	Quantitative assessment of student problem applications	1, 2 Engaging in Argument from Evidence Planning and Carrying Out Investigations Using Mathematics and Computational Thinking Obtaining, Evaluating, and Communicating Information – Constructing Explanations and Designing Solutions

Unit #: 4	Unit Name: Electric Field & Gauss	Unit Length: 4 wks

ESSENTIAL QUESTIONS:

How can we further manipulate the secrets of an Electric Field to yield more electrical energy for less cost to mankind?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	HS-PS1-3
2	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	HS-PS2-4
3	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

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 Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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	**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-PS1-3) • 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. (secondary to HS-PS1-1),(secondary to HS-PS1-3)	**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-PS1-3), (HS-PS2-4)

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-PS1-3) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomena to describe explanations. (HS-PS2-4) **Constructing Explanations and Designing Solutions**	**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) ● 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-PS2-4) **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- ETS1-2)	

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. - 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) **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)		

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-PS1-3)

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-PS1-3)

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-PS1-3)

Math:

MP.2 Reason abstractly and quantitatively. (HS-PS2-4)

MP.4 Model with mathematics. (HS-PS2-4)

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-PS2-4)

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-4)

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-4)

HSA.SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (HS-PS2-4)

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-PS2-4)
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. **Career Ready Practices:** 1-12	

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Electric Field Electric Force Charge Density Gauss Law Gaussian Electric Flux Surface Electric Potential	Analysis Integration Vector Function Theorize Assessment Evaluate	Computer for virtual Electric Field Lab or E Field Probe kit Voltmeter Multimeter

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Video: Is it Electric? (Defining and describing Fields)	1 Asking Questions and Defining Problems
	Discussion (Where are electric fields in modern Devices?)	1 Asking Questions and Defining Problems
EXPLORE	**Examples of Exploring Activities:**	
	Virtual Electric Field (Using virtual probes in a field)	1, 2 Asking Questions and Defining Problems Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data
	Field Probe Lab (predict electric field values)	1, 2 Asking Questions and Defining Problems

		Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data
EXPLAIN	**Examples of Explaining Activities:**	
	Lab Analysis and Theoretical applications (lab breakdown and application of some of the problems)	1, 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
	Simple Problem Solving (mostly elementary applications first)	1, 2, 3 Asking Questions and Defining Problems Using Mathematics and Computational Thinking

ELABORATE	Examples of Elaborating Activities:	
	More Advanced Problem Solving (dissection and analysis of theoretical field situations)	2, 3 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
	Mini lecture and video (Gaussian surface and calculations for different surfaces)	1, 2, 3 Asking Questions and Defining Problems Using Mathematics and Computational Thinking
EVALUATE	**Examples of Evaluating Activities:**	
	Compare and contrast sample Gaussian field results	1, 3 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

	Self-Evaluation of problem breakdown, analysis and results	1, 2, 3 Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information

Unit #: 5	Unit Name: Electric Circuits	Unit Length: 4 wks.

ESSENTIAL QUESTIONS:

How can we determine if there are limits to circuit sizes and applications?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	Students should relate voltage to resistance, write relationship between field and current density, calculate equivalent resistance in a circuit, design a series parallel circuit, setup and solve simultaneous equations for unknown resistances?	LO's for AP Physics C – III. Electricity & Magnetism- C. Electric Circuit - Resistance
2	Describe, setup and measure capacitance in a circuit, determine voltage ratios with capacitors, analyze and sketch graphs for the capacitance performance?	Electricity & Magnetism- C. Electric Circuit - Capacitance

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 Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design:	**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. (secondary to HS-PS2-6) **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	**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** • Empirical evidence is required to differentiate between cause and correlation and make claims about

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) **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and	of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • 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-PS2-4),(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),*(secondary to HS-PS1-1)*,*(secondary to HS-PS1-3)* **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)*	specific causes and effects. (HS-PS2-1),(HS-PS2-5) • 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)

progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)	**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-PS2-3)* **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. *(secondary to HS-PS2-3)*	

Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. ● 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)		

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-PS2-5)

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-PS2-5)

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)
MP.4	Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)
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)
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)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)
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),(HS-PS2-4)
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. **Career Ready Practices:** 1-12	

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Capacitance Series/Parallel Dielectric Current/Density Resistance Resistivity Kirchoff Rule RC Circuit Charge/Discharge	Analysis Correlation Summation Integration Prediction Evaluation	Circuit Diagrams Electric leads, meters, power source Resistors, Capacitors, Switches Computer for Virtual circuit analysis Or Electric Box kit

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Video (Intro to Electric Circuits)	1 Asking Questions and Defining Problems
	Phone, keyboard Capacitors (observation and response)	1 Asking Questions and Defining Problems
	Discussion (Where are the circuit and how do they differ?)	1, 2 Asking Questions and Defining Problems Obtaining, Evaluating, and Communicating Information
EXPLORE	**Examples of Exploring Activities:**	
	Virtual Circuit Lab (Probe different values and see how they relate)	1, 2 Asking Questions and Defining Problems Planning and Carrying Out Investigations Obtaining, Evaluating, and Communicating Information
	Capacitor Circuit Lab (Charge and discharge capacitor through a large resistor)	1, 2 Planning and Carrying Out Investigations * Analyzing and Interpreting Data Using Mathematics and Computational Thinking Obtaining, Evaluating, and Communicating Information

	Parallel Circuit Lab (Series vs Parallel)	1, 2 Planning and Carrying Out Investigations Analyzing and Interpreting Data Using Mathematics and Computational Thinking
EXPLAIN	**Examples of Explaining Activities:**	
	Experimental vs Theoretical Results (Problems explored before relate to lab)	1, 2 Developing and Using Models Analyzing and Interpreting Data Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information
	Lab Analysis (What circuit values predicted accurately – degree of error)	1, 2 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
ELABORATE	**Examples of Elaborating Activities:**	
	Theoretical problems explained and analyzed	1, 2

		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
	Video on Applying Kirchoff Rules to Circuits	1 Asking Questions and Defining Problems
EVALUATE	**Examples of Evaluating Activities:**	
	Self-Evaluation of all parts of Circuit progress compared to theoretical	1, 2 Constructing Explanations and Designing Solutions Obtaining, Evaluating, and Communicating Information
	Quantitative Assessment of student progress by teacher	1, 2 Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions Engaging in Argument from Evidence/Obtaining, Evaluating, and Communicating Information

Unit #: 6	**Unit Name: Electromagnetism**	**Unit Length: 4 wks**

ESSENTIAL QUESTIONS:

How can we apply the laws of electromagnetism to aid us in developing new standards of human health?

#	STUDENT LEARNING OBJECTIVES (SLO)	Corresponding DCIs and PEs
1	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.	HS-PS2-5
2	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.	HS-PS3-5

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 Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models. • 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	**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. (secondary to HS-PS2-6) **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	**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** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5)

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) **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on	fields cause electric fields. (HS-PS2-4),(HS-PS2-5) **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)*	• 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) **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)

mathematical models of basic assumptions. ● Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4)		

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-PS2-5), (HS-PS3-5)

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-PS2-5), (HS-PS3-5)

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)
MP.4	Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)
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)
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)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)
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),(HS-PS2-4)
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. **Career Ready Practices:** 1-12	

Unit Plan		
Content Vocabulary	**Academic Vocabulary**	**Required Resources**
Magnetic Field Magnetic Flux Magnetic Moment Biot Savart Ampere's Law Faraday's Law Electromagnetic Induction Lenz Law Generator/Motor	Analysis Integration Process Prediction Assessment Evaluation	Magnets Coils Emf (Voltage) Source Multimeters

THE 5 "E"s	Examples of Learning Activities for the specified "E"	SLO's and Engineering Practices
ENGAGE	**Examples of Engaging Activities:**	
	Video (Electromagnetic Properties)	1 Asking Questions and Defining Problems
	Demonstrations (Generation of currents and magnetic fields)	1 Asking Questions and Defining Problems
	Discussion (How do electrical devices work?)	1 Asking Questions and Defining Problems Developing and Using Models
EXPLORE	**Examples of Exploring Activities:**	
	Magnetism mini lab (Observe poles and shape with iron filings)	1 Asking Questions and Defining Problems Planning and Carrying Out Investigations
	Electromagnetic Induction lab (Observe and measure deflections with Galvanometer)	1, 2 Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data Using Mathematics and Computational Thinking
EXPLAIN	**Examples of Explaining Activities:**	
	Lab Analysis of previous considering prediction of current generation	1, 2 Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data

		Using Mathematics and Computational Thinking Engaging in Argument from Evidence
	Motor – Generator application (Detail Faraday induction with these devices)	1, 2 Developing and Using Models Planning and Carrying Out Investigations Constructing Explanations and Designing Solutions
ELABORATE	**Examples of Elaborating Activities:**	
	Prediction of Results and compare to theoretical values	1, 2 Developing and Using Models Analyzing and Interpreting Data Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information
	Mini lecture and video on Faraday Induction, magnetic flux and problems	1 Asking Questions and Defining Problems Using Mathematics and Computational Thinking Obtaining, Evaluating, and Communicating Information

EVALUATE	Examples of Evaluating Activities:	
	Compare and contrast all experimental and theoretical values to lab analysis and problems	1, 2 Planning and Carrying Out Investigations Constructing Explanations and Designing Solutions Analyzing and Interpreting Data Engaging in Argument from Evidence
	Student self-evaluation of structure, process and results of electromagnetic applications	1, 2 Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information