Washington Township School District

__The mission of the Washington Township Public Schools__ is to provide a safe, positive, and progressive educational environment that provides opportunity for all students to attain the knowledge and skills specified in the NJ Learning Standards at all grade levels, so as to ensure their full participation in an ever-changing world as responsible, self-directed and civic-minded citizens.

Course Title:	**Advanced Placement Physics C**
Grade Level(s):	**12**

Duration:	*Full Year:*	**X**	*Semester:*		*Marking Period:*	
Course Description:	AP Physics C is a calculus based advanced physics course intended for students interested in pursuing a career in the fields of engineering/science. The content and course design is equivalent to that of the first two semesters of collegiate physics as taught at most competitive engineering schools in the United States. The textbook, *Physics for Scientists and Engineers*, by Serway and Jewett, is used in colleges throughout the country. The course emphasizes developing systems analysis/problem solving skills that focus on the application of general physics principles to specific situations. Laboratory skills and experiment design are stressed to introduce the student to the engineering experience. The first 16 weeks are for the Mechanics portion. Topics are: Motion in One and Two Dimensions, Newton's Laws, Circular Motion, Energy & Momentum, Angular Mechanics, Equilibrium, Simple Harmonic Motion and Gravitation. The Electricity & Magnetism portion follows immediately. Another 15 weeks is spent on Electrostatics, Circuit Analysis, Magnetic Fields and Electromagentism. After completing the above described course work, 3 weeks are spent reviewing for two AP Exams (Mechanics, and Electricity & Magnetism). After the AP Exams, during the last 3-4 weeks of school, the focus switches to Modern Physics topics; learning Einstein's Theories of Relativity, Particle/Wave Duality, and introduction to the basics of Quantum Physics.					
Grading Procedures:	Tests: 50%, Quizzes: 15%, Independent Problem Solving: 15 %, Lab work: 20 %					
Primary Resources:	**"Physics for Scientists and Engineers", 9th Ed, Serway and Jewett** **Next Generation Science Standards NGSS** **New Jersey Student Learning Standards NJSLS**					

Washington Township Principles for Effective Teaching and Learning

- Implementing a standards-based curriculum
- Facilitating a learner-centered environment
- Using academic target language and providing comprehensible instruction
- Adapting and using age-appropriate authentic materials
- Providing performance-based assessment experiences
- Infusing 21st century skills for College and Career Readiness in a global society

Designed by:	Denise Merrill
Under the Direction of:	Dr. Patricia Hughes

Written: ___________________________________

Revised: ___________________________________

BOE Approval: ______________________________

Unit Title: Kinematics / Newton’s Laws of Motion

Unit Description:

Kinematics is a mathematical description of motion. One dimensional and two dimensional motion will be studied. Topics will include reference frames, vector analysis, Galileo’s Law of Falling Bodies, and projectile motion. The nature of accelerated motion will be stressed.

Newton’s Laws of Motion form the basis of all classical mechanics. Outside of the extremes involving the atomic scale and speeds approaching that of light, Newton’s laws from the 17^{th} century still provide the foundation to understanding the behavior of our universe.

Topics of study will include his three laws of motion and mathematical applications of these laws to systems analysis. An elementary introduction to The Calculus (also developed by Newton) and the manner in which it elegantly allows the application of Newton’s laws to physical systems will be included.

Calculus (differential/integral) will be introduced, both mathematically and graphically, by directly applying to kinematics problems.

Unit Duration: 6 weeks

Desired Results

Standard(s):

- 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)
- 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)
- Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4)

Indicators:

- Forces and Motion: Newton’s second law accurately predicts changes in the motion of macroscopic objects. (PS2.A)
- Engineering Design: Optimizing the Design Solution (ETS1.C)
  - o 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.
- Engineering Design: Developing Possible Solutions (ETS1.B)
  - o 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 a persuasive presentation to a client about how a given design will meet his or her needs.

Understandings:

Students will understand that…

Newton’s Laws of Motion form the basis of classical mechanics and underlie the conceptual approach to the practice of all the sciences.

Motion is a relative physical quantity requiring an established frame of reference to be defined.

Changes in the state of motion of a body (acceleration) must be caused by an uneven force.

Calculus provides the most elegant expression of Newton’s Laws of Motion.

Essential Questions:

1. What is an inertial frame of reference?
2. What does it mean to move?
3. What is acceleration?
4. What does a vector represent?
5. How is vector mathematics similar to right triangle geometry?
6. How does the Law of Falling Bodies affect objects experiencing projectile motion?
7. What is a force?
8. What are the fundamental forces in nature?
9. What is the relationship between mass and inertia?
10. How is the motion of an object affected by each of the following: zero net force, a net force greater or less than zero, and a perpendicular net force?
11. What is a Newton’s third law force pair?

12. How can the forces on an object be represented visually and then be used to predict the behavior of that object?
13. How are field forces different from contact forces? How are they alike?
14. What are examples of everyday forces, and how can they be incorporated in the analysis of a system?
15. How can a basic understanding of forces and motion be utilized to design and construct a device that can launch a projectile to a required location?

Assessment Evidence

Performance Tasks:

Students will:

- Apply mathematics, (algebra, geometry, trigonometry, calculus), to the analysis of moving bodies.
- Use vector mathematics to analyze two-dimensional motion.
- Use the principles of kinematics to describe the behavior of acceleration bodies.
- Incorporate the Law of Falling Bodies into their analysis of moving bodies.
- Develop proper techniques for creating appropriate experiments in the laboratory.
- Apply Newton's Laws of Motion to systems analysis involving multiple forces, inclined surfaces, and frictional forces.
- Develop their ability to apply mathematical skills to the analysis of physical systems.
- Recognize Calculus as the most elegant technique for applying Newton's Laws of Motion.
- Design hands-on experiments to explore the applicability of Newton's Laws to physics systems in the laboratory.

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

In class and independent quizzes (appropriate topics include):

- 1-Dimensional Kinematics, concepts and problems
- Motion Graphs
- 2-D Kinematics, concepts and problems
- Free Body Diagrams
- Newton's Laws (concepts and practice applications)

Independent work such as:

- Completion of online and written problem sets
- Partial and/or full formal laboratory reports
- Participation in online discussion groups

Tests

- 1-D and 2D Kinematics
- Newton's Laws

Quiz

- Kinematics
- Circular Motion

Benchmark: Predict the landing location of a projectile launched from a different height for a variety of angles

Learning Plan

Learning Activities:

The concepts in this unit are presented in Serway and Jewett's *<u>Physics for Scientists and Engineers, 9th Ed.</u>* *in chapters 2-6 (2.1 – 2.8, 3.1 – 3.1 - 3.4, 4.1 – 4.6, 5.1 – 5.8, 6.1 – 6.4)*

For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

One dimensional motion

<u>Calculus Introduction:</u>

1. What is a derivative? How can it be shown on a graph?
2. What is an integral? How can it be shown on a graph?
3. What are the steps of taking a derivative and integral of a function, and how can these relate to physics?
   <u>Suggested Activities:</u>

Generating graphs, basic practice problems, video tutorials, take an algebra-based problem and convert to a Calculus-based problem.

Kinematics (Motion):

1. 1-dimensional kinematics (straight-line motion with and without constant acceleration)
   Topics:
   distance vs. displacement, speed vs. velocity, basic concept of vectors
   motion (dot) diagrams
   motion/kinematics graphs (distance-time, position-time, speed-time, velocity-time, acceleration-time)
   free-fall acceleration
   Suggested Activities:
   Generating all motion graphs, Rolling Ball (Vernier Video Analysis), Physics Aviary PVC Free Fall Analysis, Physics Aviary graphing Motion Lab 2 – to generate Excel graphs for x, v, and a vs t. Vernier Free Fall Lab, Demon Drop (Vernier Video Analysis), Motion on an Incline (Student Inquiry Lab using available materials and probes), Equations of Motion (Physics Aviary), Problem sets from text and Cengage WebAssign Chapter 2.
   (Suggested Ch 2 Problem Set: 1, 4, 5, 6, 14, 19, 20, 21, 24, 25, 31, 48, 50, 51, 58, 59, 62, 73)

2. 2-dimensional kinematics (focus on projectile motion)
   Topics:
   Resolving vectors into components
   Adding vectors
   Multiplying & Dividing Vectors
   Analysis of objects undergoing projectile motion (graphical and mathematical)
   -include non-zero angle launches

   Suggested Activities: Vector Addition (PhET), Creation and analysis of graphs of displacement, velocity and acceleration for the x and y components of PM vectors; Calculate range, time in flight, maximum height, etc. for horizontally launched projectiles and projectiles launched a non-zero angle; Predict landing location for an actual projectile; Projectile Motion (PhET), Drone Delivery Challenge (Physics Aviary), Problem sets from Cengage WebAssign Chapter 3 and 4.
   (Suggested Ch 3 Problem Set: 1, 3, 4, 6, 11, 15, 19, 24, 23, 27, 29, 31, 51)
   (Suggested Ch 4 Problem Set: 1, 5, 6, 7, 9, 13, 16, 20, 21 23, 27, 60, 74, 75, 78, 84, 89)

Forces & Newton's Laws:

3. Newton's Laws
   Topics:
   Force as a vector quantity that is basically a push or pull
   Four fundamental forces
   Free Body Diagrams, Defining system of interest
   History (Newton's story)
   Newton's 1st Law (conceptual)
   Newton's 2nd Law (conceptual)
   Newton's 3rd Law (conceptual)
   Suggested Activities: Newton's Laws (hands-on activities exploring each of Newton's laws of motion), Lab: Newton's 2nd Law (student-designed inquiry lab)

4. Applications of Newton's Laws
   Topics:
   Applications will include the analysis of the following types of systems:
   Object(s) in equilibrium, object(s) experiencing net external force (due to any combination of: friction, tension, other "applied forces", gravity, normal force, drag force, buoyant force), object(s) on an incline, connected objects, terminal velocity, Atwood machines, multiple objects connected.
   Suggested Activities: Friction Lab (stopping distance or friction on incline), Newton's 2nd Law Lab simulation (Physics Aviary), Coffee-Filter Lab to determine forces on object at terminal velocity, Problem Set from Cengage WebAssign for Chapter 5
   (Suggested Ch 5 Problem Set: 2, 3, 11, 13, 17, 12, 19, 22, 28, 31, 32, 34, 49, 42, 45, 47, 61, 64, 65, 84, 85, 89 95 96, 101, 103)

5. Circular Motion
   Topics:
   Tension and Normal forces of objects in circular motion, conical pendulum, maximum speed of a car on a banked or unbanked road, non-uniform circular motion.
   Suggested Activities: Circular Motion Lab (Stopper on a string with weights – determine "g"). Vernier Circular Motion Apparatus Lab activity, Cengage WebAssign Chapter 6
   (Suggested Ch 6 Problem Set: 1, 3, 5, 8, 9, 11, 12, 16, 19, 17, 21, 48, 54, 57, 58, 59, 61, 63)

Further Information regarding suggested activities:

❖ Use of Vernier LoggerPro™ for video analysis of simple motions, which generates motion dot diagrams as well as motion graphs and data tables; pre-written activities are found within the program (which is on student devices), alternately, students can film motion in (or out of) lab and use the program to analyze it.

❖ Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of motion, including constant velocity, constant acceleration, and free fall acceleration

❖ Use of online simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.

❖ Use of WebAssign
  - Study Area activities for chapters 2-6 (including practice questions, practice problems, and video demonstrations)
  - Teacher-selected questions and problems for independent work (chapters 2-6)
  - Students will read selected sections of textbook via e-book (chapters 2-6)

❖ Online video tutorials are widely available to explain Kinematics and Newton's Laws of Motion topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
  - Flipping Physics with Jonathan Thomas-Palmer

Resources:

Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

The College Board, www.collegeboard.org.
College Board AP Physics C Course Description: http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-c-course-description.pdf

McCulley, Frank. "The Physics Aviary." The Physics Aviary. N.p., 2017. Web. 28 June 2017
http://www.thephysicsaviary.com/

Next Generation Science Standards, http://www.nextgenscience.org/

New Jersey Student Learning Standards, www.nj.gov/education/cccs

"Next Time Questions" Paul Hewett, http://www.arborsci.com/next-time-questions

"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (NGSS HS PS2.A) *This Goal and Scale specifically addresses one-dimensional motion.*	
4.0	**Students will be able to:** • Design, conduct, and analyze data from, an experiment that allows students to measure the terminal velocity of a falling object, and use Calculus to derive the equations that model its motion.
3.0	**Students will be able to:** • Represent straight-line motion using multiple representations (graphically, pictorially, or mathematically) • Determine average speed and/or average velocity for an object that undergoes several changes in speed/velocity during a trip. • Analyze the motion of an object using multiple step problem solving strategies
2.0	**Students will be able to:** • Recognize and/or define the following terminology related to the analysis of an object under the influence of one or more forces: displacement, velocity, acceleration, vector, scalar, coordinate system. • Use the equations of kinematics for a body undergoing constant (or zero) acceleration to solve for an unknown quantity. • Recognize the features of a position time graph and those of a velocity time graph. • Determine average speed, average velocity, average acceleration, and instantaneous values for speed, velocity and acceleration using mathematical formulas and/or graphical analysis • Utilize laboratory equipment to conduct an experiment testing for the value of "*g*" in the classroom. • Utilize laboratory equipment and/or video analysis software to analyze the motion of an object moving in a straight line
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (NGSS HS PS2.A) *This Goal and Scale specifically addresses two-dimensional (projectile) motion.*	
4.0	**Students will be able to:** • Design and conduct an experiment or set of experiments that can be used to predict the vertical and horizontal position of a projectile for a specified target, with limited input from the instructor.
3.0	**Students will be able to:** • Determine an unknown quantity within a system in the lab by analyzing the system, using relevant measurements and calculations. • Develop and apply an algorithm for the position of a projectile. • Solve multi-step projectile motion problems
2.0	**Students will be able to:** • Recognize and/or define the following terminology related to the analysis of an object under the influence of one or more forces: gravity, acceleration, vector, vector component, coordinate system. • Select the appropriate trigonometric function to solve for an unknown side of a tringle, given the hypotenuse and an angle. • Calculate the components of a vector. • Perform vector addition. • Describe the conditions of projectile motion.
1.0	**With help, partial success at level 2.0 content and level 3.0 content**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• 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. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system Provide challenge problems for advanced learners to solve
Struggling Learners	• 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). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via MyLab&Mastering) Utilize peer tutors during class to work with struggling learners
English Language Learners	• Coordinate with ELL advisors to modify activities where appropriate • 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). • Additional resources and support for English as a Second Language students can be found at : http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf
Special Needs Learners	• Follow IEP modifications and work with special education teacher to make modifications and use Differentiated Instruction Activities. • Universal Design and Learning strategies and resources can be found at the following site: http://www.nj.gov/education/udl/

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.
- HSN.Q.A.1: Use units 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.
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.
- 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.
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems.

- 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.
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- 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.

HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Unit Title: Energy/Momentum

Unit Description: Energy and momentum are fundamental concepts in science providing a powerful modeling system for analyzing complex physical systems. Topics will include work-energy theorem, mechanical energy, power, momentum and impulse, and analysis of collisions. Furthermore, the idea of conservation of physical properties will be explored in depth, focusing on conservation of energy and conservation of momentum.

Unit Duration: 3 weeks

Desired Results

Standard(s):

- 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. (HS-PS3-1)
- Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects). (HS-PS3-2)
- Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. * (HS-PS3-3)
- 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)
- Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. (HS-PS2-3)

Indicators:

- 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.
  - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- 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.
  - Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
  - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
  - The availability of energy limits what can occur in any system.
- 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)
- PS2.A: Forces and Motion
  - Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
    - 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.

Understandings:

Students will understand that…

Conservation of energy and conservation of momentum are powerful physical models that allow for description and analysis of complex systems.

Essential Questions:

1. What is the relationship between work and energy?
2. How can conservation of energy be applied to the analysis of physical systems?
3. What is momentum?
4. What is the relationship between Newton's Laws and conservation principles?
5. How can conservation of momentum be applied to the analysis of physical systems?

Conservation principles join Newton's 2nd Law in a group of mathematical models that govern the behavior of the physical universe.	6. How does one determine when best to rely on Newton's Laws versus conservation principles? 7. How does The Calculus expand the range of systems described by conservation of momentum?

Assessment Evidence

Performance Tasks: Students will: • Apply conservation of energy principles to the analysis of physical systems. • Apply conservation of momentum principles to the analysis of physical systems. • Derive conservation principles from Newton's Laws of Motion. • Identify situations in which mechanical energy is or is not conserved. • Design and implement experiments exploring the principles of conservation of energy and momentum. • Use Calculus to analyze systems involving rocket propulsion. • Use Calculus to determine the work done by a variable force. • Use the Work-Energy Theorem as a form of the principle of conservation of energy. • Describe the method to determine and the difference between a scalar product (dot product) and a cross product. • Design a lab the demonstrates the conservation of energy and / or momentum.	**Other Evidence:** Daily informal and formal formative assessments of student activities, such as: • Warm up problems/questions • Whiteboarding/problem solving sessions • Peer tutoring • Lab work (including mathematical modeling) In class and independent quizzes (appropriate topics include): • Conservation of energy with non-conservative forces and variable forces • Conservation of momentum • Independent work such as: • Completion of online and written problem sets • Partial and/or full formal laboratory reports • Participation in online discussion groups Quiz • Energy • Momentum Tests • Energy/Momentum

Benchmark:

Experimentally show that the area under the Force-Time graph equals change in momentum of an object

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 7-9 (7.1 – 7.7, 8.1 – 8.5, 9.1 – 9.7, 9.9.)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 7: Energy of a System

Topics:
Systems
Work done by a constant force
Scalar Product
Work done by a varying force
Work – Kinetic Energy Theorem
Conservative and Non-conservative Forces
Conservative Forces and Potential Energy
Suggested Activities:

Energy Skate Park (PhET), Speed from Work Graphs, Maximum Toss Height from Energy Conservation, Work-Energy Lab (using Vernier or analog equipment), "Net Work-KE", (Vernier Physics with Video Analysis), Work – KE Lab from Physics Aviary, Problem sets & video tutorials from Cengage Web Assign Chapter 7
(Suggested Ch 7 Problem Set: 2, 5, 6, 10, 11, 12, 14, 15, 25, 26, 29, 33, 35, 47, 50, 51, 55, 60)

Chapter 8: Conservation of Energy

Topics:
Non-isolated System
Isolated System
Kinetic Friction
Changes in Mechanical Energy – non-conservative forces
Power

Suggested Activities: Power Pulling Billy up a Hill, (Physics Aviary), Bungee Jumper Problem (Design Challenge Lab activity), Problem sets & video tutorials from Cengage WebAssign Chapter 8
(Suggested Ch 8 Problem Set: 1, 3, 5, 6, 7, 13, 15, 16, 22, 23, 38, 47, 57, 62. 63. 64. 65)

Chapter 9; Linear Momentum and Collisions

Topics:
Momentum
Impulse
Conservation of Momentum
Collisions (Elastic & Inelastic)
Collisions in 2 Dimensions
Center of Mass
Deformable Systems
Rocket Propulsion

Suggested Activities:
Finding Speed from Impulse Graph with variable forces, Collisions (Physics Aviary), Impulse-Momentum Lab (using Vernier), Impulse Lab (Physics Aviary), Collision Lab (Phet Simulations), Bottle Rockets (Year-end project to design and build a water-propelled soda bottle rocket), Problem sets & video tutorials from Cengage WebAssign Chapter 9 (Suggested Ch 9 Problem Set: 1, 4, 8, 11, 13, 18, 19, 23, 27, 29, 30, 32, 33, 37, 39, 41, 43, 56, 58, 60, 84, 89)

Further Information regarding suggested activities:

- Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of work, energy, impulse, and momentum.

- Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.

- Use of WebAssign Physics Assignments
  - Study Area activities for Chapters 7 -9 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapters 7 & 8 & 9)
  - Students will read textbook content via e-book (Chapters 7 & 8 & 9)

- Online video tutorials are widely available to explain Energy and Momentum topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
  - Flipping Physics with Jonathan Thomas-Palmer

Resources:

Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

The College Board, www.collegeboard.org.
College Board AP Physics C Course Description: http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-c-course-description.pdf

McCulley, Frank. "The Physics Aviary." The Physics Aviary. N.p., 2017. Web. 28 June 2017 http://www.thephysicsaviary.com/

Next Generation Science Standards, http://www.nextgenscience.org/

New Jersey Student Learning Standards, www.nj.gov/education/cccs

“Next Time Questions” Paul Hewett, http://www.arborsci.com/next-time-questions

"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): 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.A) Conservation of Energy and Energy Transfer: Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3.B)	
4.0	**Students will be able to:** • Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy, without assistance from the instructor AND can accurately explain the physical performance of that device as compared to the other devices presented. • Examine a sample explanation of the energy changes in a system to find inaccuracies, and then correct the inaccuracies, providing justification for corrections.
3.0	**Students will be able to:** • Make predictions about the changes in kinetic energy of an object based on considerations of direction of the net force on the object as the object moves. • Derive an equation relating the energy content of a system at one point in time to that of the same system at another point in time. • Use energy conservation concepts and work-energy considerations to make predictions about the motion of an object at different points in time. • Identify systems in which mechanical energy is not converted to non-mechanical forms. • Quantify the amount of mechanical energy converted to thermal energy in a system that includes a dissipative force. • 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). • Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy, with some assistance from the instructor.
2.0	**Students will be able to:** • Recognize and/or define the following vocabulary: work, energy, gravitational potential energy, elastic potential energy, kinetic energy, work-energy theorem, conservation of energy, power, conservative force, non-conservative force • Calculate work done on an object by the action of a constant force. • Calculate the gravitational potential energy of system. • Calculate the elastic potential energy of a system. • Calculate the translational kinetic energy of a moving object. • Calculate the rotational kinetic energy of an object. • Manipulate the terms in an equation to solve for an unknown variable.

1.0	**With help, partial success at level 2.0 content and level 3.0 content**
0.0	**Even with help, no success**

Unit Learning Goal and Scale (Level 2.0 reflects a minimal level of proficiency)	
Standard(s): (Momentum) 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. (PS2.A)	
4.0	**Students will be able to:** • Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
3.0	**Students will be able to:** • Predict the post interaction velocities of particles or objects within a system, based on the type of interaction in which they are involved • 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. • Predict the change in momentum of an object from the average force exerted on it and the interval of time during which the force is exerted • Design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time. • Plan and conduct an experiment testing the conservation of momentum during collisions.
2.0	**Students will be able to:** • Calculate the net external force acting on an object, as the vector sum of all of the individual forces acting on the object. • State, verbally and via momentum equations, the impulse-momentum theorem. • State, verbally and via momentum equations, the law of conservation of momentum. • Calculate the linear momentum of an individual particle or object. • Calculate the total momentum of a system of objects. • Describe the path of the center of mass of an object • Recognize that the change in momentum of the center of mass of a system is zero if all forces acting are internal to the system.
1.0	**With help, partial success at level 2.0 content and level 3.0 content**
0.0	**Even with help, no success**

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World

Cause and Effect <u>Connections to Nature of Science:</u> Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Unit Modifications for Special Population Students	
Advanced Learners	• 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. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system Provide challenge problems for advanced learners to solve
Struggling Learners	• 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). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via MyLab&Mastering) Utilize peer tutors during class to work with struggling learners
English Language Learners	• Coordinate with ELL advisors to modify activities where appropriate • 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). • Additional resources and support for English as a Second Language students can be found at : http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf
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Interdisciplinary Connections

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- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
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- MP.4: Model with mathematics.
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- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.

- 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.
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems.
- 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.
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- 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.

HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Angular Mechanics

Unit Description:

Rotational motional is described by angular mechanics. All of the fundamental models presented to date (Kinematics, Energy, Momentum) will be applied to the motion of bodies experiencing movement about a fixed point in space. The physical quantities studied in previous units will be shown to be represented by analogous quantities in angular mechanics.

Unit Duration: 3 weeks

Desired Results

Standard(s):

- 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)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.
- ETS1.A: Defining and Delimiting an Engineering Problem

Understandings:

Students will understand that…

The mathematical models studied in Physics are fundamental in that these models are applicable to all physical systems.

Rotational motion is analyzed using the same principles used to describe linear motion, only in the details of application is variance noted.

Essential Questions:

1. What is rotational motion?
2. What are the rotational analogs in angular mechanics for the linear quantities studied earlier in the curriculum?
3. How does rotational motion differ from linear motion?
4. How does physics apply to rolling motion?
5. How do Newton's Laws of Motion apply to angular mechanics?

Assessment Evidence

Performance Tasks:

Students will:

- Apply Newtonian mechanics to objects experiencing rotational motion.
- recognize that the mathematical models studied in Physics and fundamental to the degree that they apply to all systems.
- Recognize that once the fundamentals are mastered alternative physical situations can be analyzed by minor adjustments to the fundamentals.
- Derive algebraic expressions for moments of inertia using Integral Calculus.
- Write down, justify and apply the relation between linear and angular velocity, or between linear and angular acceleration, for an object of circular cross-section that rolls without slipping along a fixed plane, and determine the velocity and acceleration of an arbitrary point on such an object.
- Apply the equations of translational and rotational motion simultaneously in analyzing rolling with slipping.
- Calculate the total kinetic energy of an object that is undergoing both translational and rotational motion, and apply energy conservation in analyzing such motion.

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

In class and independent quizzes (appropriate topics include):

- Determine moment of inertia for point objects and continuous objects
- Rotational Kinematics

Independent work such as:

- Completion of online and written problem sets
- Partial and/or full formal laboratory reports
- Participation in online discussion groups

Quiz

- Rotational Kinematics
- Angular Momentum

Tests

- Angular Mechanics

- Use the vector product and the right-hand rule, so they can:
  - Calculate the torque of a specified force about an arbitrary origin.
  - Calculate the angular momentum vector for a moving particle.
- Calculate the angular momentum vector for a rotating rigid object in simple cases where this vector lies parallel to the angular velocity vector.
- Design an experiment that experimentally determines the moment of inertia of an object.

Benchmark:

Experimentally determine the Moment of Inertia of an object

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 10-11 (10.1 – 10.9, 11.1 - 11.4)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 10: Rotation of a Rigid Object About A Fixed Axis

Topics:
Angular Kinematics
Rigid Object Under Constant Angular Acceleration
Angular and Translational Quantities
Torque
Moment of Inertia
Rotational Kinetic Energy
Rolling

Suggested Activities: Rotational Kinematics and Rotational Mechanics Vernier Lab Kit, Kinetic energy of rolling rigid object demonstration and exploration (using variable Moment of Inertia disks), determine moment of inertia of various point systems, Moment of Inertia Lab from Physics Aviary, Problem sets and video tutorials from Cengage WebAssign Chapter 10.
(Suggested Ch10 Problem Set: 3, 4, 5, 6, 7, 12, 27, 32, 35, 43, 44, 45, 47, 48, 49, 53, 55, 56, 59, 61, 64, 67, 73, 77, 78, 79, 92)

Chapter 11: Angular Momentum

Topics:
Vector Product
Angular Momentum – Non-isolated and Isolated System
Conservation of Angular Momentum

Suggested Activities: Vernier Rotational Lab Activity kit exploring conservation of angular momentum, Problem sets & video tutorials from Cengage WebAssign Chapter 11
(Suggested Ch 11 Problem Set: 1, 3, 7, 11, 12, 18, 19, 23, 25, 30, 31, 34, 37, 39, 49, 51 a, 52, 55, 61)

Further Information regarding suggested activities:

- ❖ Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of moment of inertia, rotational kinematics and angular momentum.
- ❖ Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)
- ❖ Use of WebAssign Physics Assignments
  - Study Area activities for Chapters 10-11 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapters 10 & 11)
  - Students will read textbook content via e-book (Chapters 10 & 11)
- ❖ Online video tutorials are widely available to explain Angular Mechanics topics clearly. Examples of helpful sites are:

- APPhysicslectures.com (stand-alone website, also available on YouTube)
- Doc Schuster (YouTube)
- APlus Physics with Dan Fullerton
- Flipping Physics with Jonathan Thomas-Palmer

Resources:

Serway and Jewett, “Physics for Scientists and Engineers”, 9th Ed., Cengage 2014

The College Board, www.collegeboard.org.
College Board AP Physics C Course Description: http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-c-course-description.pdf

McCulley, Frank. "The Physics Aviary." The Physics Aviary. N.p., 2017. Web. 28 June 2017 http://www.thephysicsaviary.com/

Next Generation Science Standards, http://www.nextgenscience.org/

New Jersey Student Learning Standards, www.nj.gov/education/cccs

“Next Time Questions” Paul Hewett, http://www.arborsci.com/next-time-questions

"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): **Forces and Motion: Newton’s second law accurately predicts changes in the motion of macroscopic objects. (NGSS HS PS2.A)**	
4.0	**Students will be able to:** • Plan and carry out an investigation relating torque to changes in angular velocity, with minimal assistance from the instructor. • Recognize the meaning of graphs of angular quantities in the analysis of data from such an experiment, and use those graphical quantities to determine the mathematical relationship between the torque on the body and its angular acceleration.
3.0	**Students will be able to:** • Apply Newton’s 2nd law to analyze a system or body experiencing one or more torques. • Determine the net torque on an object. • Compare the torques on an object caused by various forces. • Correctly draw extended body diagrams to represent the application of forces on an object. • Make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis. • Plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.
2.0	**Students will be able to:** • List the angular analogs of the linear quantities presented earlier in the course. • Replace the linear quantities with their angular analogs in kinematics equations. • Solve for unknown angular quantities associated with an object undergoing rotational motion, using the kinematics equations. • State Newton’s 2nd law as applied to torque, angular acceleration, and moment of inertia. • Recognize that Newton’s second law can be applied to systems experiencing angular acceleration (or zero acceleration) under the action of one or more torque. • Define torque and moment of inertia. • Calculate the moment of inertia of an object, given a list of possible formulas.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• 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. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system Provide challenge problems for advanced learners to solve
Struggling Learners	• 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). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via MyLab&Mastering) Utilize peer tutors during class to work with struggling learners
English Language Learners	• Coordinate with ELL advisors to modify activities where appropriate • 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). • Additional resources and support for English as a Second Language students can be found at : http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf
Special Needs Learners	• Follow IEP modifications and work with special education teacher to make modifications and use Differentiated Instruction Activities. • Universal Design and Learning strategies and resources can be found at the following site: http://www.nj.gov/education/udl/

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
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Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.
- HSN.Q.A.1: Use units 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.
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- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- 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.

HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Equilibrium

Unit Description:

Static equilibrium describes a rigid body at rest. Conditions required are forces and torques summing to zero. Conditions of static equilibrium are of particular importance to civil and mechanical engineers as well as architects. Students of these and related disciplines will receive a strong foundation in the applications of Newton's Laws to common systems in equilibrium in preparation for more advanced studies in statics.

Unit Duration: 1 week

Desired Results

Standard(s):

- 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)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.

Understandings:

Students will understand that…

Newton's Laws have direct application in the design and construction of homes, buildings, bridges, and all structures.

Equilibrium conditions are analyzed using Newton's 2nd and 3rd Laws in particular forming a foundation for the principles of statics to be studied by engineering students.

Essential Questions:

1. What conditions are required for static equilibrium?
2. How are Newton's Laws applicable to rigid bodies in equilibrium?
3. Where in engineering careers are Newton's Laws directly applicable?
4. What is center of mass?
5. How is the center of mass of a rigid body determined?

Assessment Evidence

Performance Tasks:

Students will:

- Determine the location of the center of gravity for uniform and irregular shaped rigid objects.
- Analyze systems involving rigid bodies in states of static equilibrium.
- Recognize that systems analysis of static equilibrium form the foundation of several types of engineering and architecture.

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

Independent work such as:

- Completion of online and written problem sets
- Partial and/or full formal laboratory reports

Quiz

- Static Equilibrium

Benchmark:

Perform "Bridge Lab" and determine accuracy of force sensors

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 12 (chapter 12.1 – 12.3)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 12: Static Equilibrium and Elasticity

Topics:
Rigid Object in Equilibrium
Center of gravity

Examples of Objects in Static Equilibrium

Suggested Activities: Static equilibrium lab using Vernier Force Sensors, Balancing Act (PHeT Simulation), Suspension Bridge (Physics Aviary), Rotational Equilibrium Levels 1 & 2 (Physics Aviary), Finding Mass from Torque (Physics Aviary), Walk the Plank (Physics Aviary), Bridge Activity (spaghetti bridge or file folder bridge design activity), Problem sets and video tutorials from Cengage WebAssign Chapter 12.
(Example Ch 12 Problem Set: 9, 10, 12, 43, 45)

Further Information regarding suggested activities:

- Use of Vernier LoggerPro™ and sensors for experimental development of equilibrium, where the sum of forces and the sum of torques equals zero.

- Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)

- Use of WebAssign Physics Assignments
  - Study Area activities for Chapter 12 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapter 12)
  - Students will read textbook content via e-book (Chapter 12)

- Online video tutorials are widely available to explain Static Equilibrium topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
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"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): **Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. (NGSS HS PS2.A)**	
4.0	**Students will be able to:** • Identify and/or calculate forces and torques in a more complex equilibrium scenario (ie- ladder leaning on frictionless wall). • Design and construct a "bridge" that could withstand a pre-determined load from very thin materials (such as spaghetti or file folders).
3.0	**Students will be able to:**

	• Caluculate the magnitude of force at a specified location required to balance the torques on an extended object/system. • Plan and conduct an experiment that analyzes forces and torques on a body/system. • Predict which objects will or will not topple/experience an angular acceleration based on the location of the center of gravity relative to support.
2.0	**Students will be able to:** • Determine the net torque on an object. • Compare the torques on an object caused by various forces. • Correctly draw extended body diagrams to represent the application of forces on an object. • State the conditions for equilibrium. • Compare and contrast stable equilibrium, unstable equilibrium, and neutral equilibrium, and evaluate objects as being in one of these three forms of equilibrium. • Define leverage and lever arm. • Locate the center of gravity of an object by balance.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students

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HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Oscillations

Unit Description:

Periodic motion is one of the most prevalent types of motion in nature. A special case involving a restoring force directed towards equilibrium position, simple harmonic motion, can be used to model many physical systems involving oscillations, from swing sets to vibrating atoms to electromagnetic wave oscillations in circuits. Oscillating mechanical systems will be analyzed to explore the physics of simple harmonic motion.

Unit Duration: 1.5 weeks

Desired Results

Standard(s):

- 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)
- 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. (HS-PS3-1)
- Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). (HS-PS3-2)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.
- PS3.A: Definitions of Energy
  - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- 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.
  - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.

Understandings:

Students will understand that…

Oscillatory motion is common throughout nature.

A system in equilibrium, when disturbed, will harmonically oscillate as a restoring force drives the system back to the lower energy equilibrium position.

Using Calculus, in conjunction with Newton's Laws of Motion, reveals an elegant description of simple harmonic motion.

Essential Questions:

1. What conditions are required to classify a motion as simple harmonic?
2. How do Newton's Laws apply to the analysis of harmonically oscillating systems?
3. How is energy conservation involved in simple harmonic motion?
4. How is the period of harmonic motion described using The Calculus?
5. What is the relationship between uniform circular motion and simple harmonic motion?

Assessment Evidence

Performance Tasks:

Students will:

- Recognize the required characteristics of simple harmonic motion.
- Experimentally explore the physical quantities that determine the period of an oscillating system.
- Use Calculus to derive algebraic models of the period of several oscillating systems.

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

• Use newton's Laws to establish the mechanics of harmonically oscillating systems. • Sketch or identify a graph of displacement as a function of time, and determine from such a graph the amplitude, period and frequency of the motion. • State how the total energy of an oscillating system depends on the amplitude of the motion, sketch or identify a graph of kinetic or potential energy as a function of time, and identify points in the motion where this energy is all potential or all kinetic. • Develop a qualitative understanding of resonance so they can identify situations in which a system will resonate in response to a sinusoidal external force.	In class and independent quizzes (appropriate topics include): • Pendulum (regular, physical and torsional) Independent work such as: • Completion of online and written problem sets • Partial and/or full formal laboratory reports Tests • Simple Harmonic Motion

Benchmark:

Design an experiment to graphically show the displacement, velocity, and acceleration as a function of time of a spring-mass-oscillator

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 15.(sections 15.1 – 15.5, 15.6 – 15.7 optional)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 15: Oscillatory Motion

Topics:
Hooke's Law
Mass Spring Oscillator
Particle in Simple Harmonic Motion
Energy of a Simple harmonic Oscillator
SHM and Circular Motion
Pendulums
Damped Oscillations (conceptual)
Forced Oscillations and Resonance (conceptual)

Suggested Activities: Spring-Mass Oscillator Lab/graphically determine the spring constant, Masses and Springs (Phet simulations), Problem sets and video tutorials from Cengage WebAssign Chapter 15.
(Suggested Ch 15 Problem Set: 4, 5, 8 9, 14, 18, 19, 22, 24, 25, 27, 39, 41, 42, 43, 45, 68)

Further Information regarding suggested activities:

❖ Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of simple harmonic motion.

❖ Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)

❖ Use of WebAssign Physics Assignments
  - Study Area activities for Chapter 15 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapters 15)
  - Students will read textbook content via e-book (Chapters 15)

❖ Online video tutorials are widely available to explain Simple Harmonic Motion topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
  - Flipping Physics with Jonathan Thomas-Palmer

Resources:
Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

The College Board, www.collegeboard.org.
College Board AP Physics C Course Description: http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-c-course-description.pdf

McCulley, Frank. "The Physics Aviary." The Physics Aviary. N.p., 2017. Web. 28 June 2017 http://www.thephysicsaviary.com/

Next Generation Science Standards, http://www.nextgenscience.org/

New Jersey Student Learning Standards, www.nj.gov/education/cccs

"Next Time Questions" Paul Hewett, http://www.arborsci.com/next-time-questions

"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu

Unit Learning Goal and Scale

(Level 2.0 reflects a minimal level of proficiency)

Standard(s): Relationship between Energy and Forces
Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)

4.0	**Students will be able to:** • Design and conduct an experiment to collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force and to develop a mathematical model to represent that motion.
3.0	**Students will be able to:** • 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.
2.0	**Students will be able to:** • describe the general behavior of an oscillator. • give examples of common systems that involve oscillation. • describe the requirements for simple harmonic motion. • use Hooke's Law to mathematically define the restoring force in such a system. • analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown. • make quantitative calculations of the internal potential energy of a system in simple harmonic motion from a description or diagram of that system. • calculate changes in kinetic energy and potential energy of a system in simple harmonic motion, using information from representations of that system.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students

Advanced Learners	• 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. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system Provide challenge problems for advanced learners to solve
Struggling Learners	• 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). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via MyLab&Mastering) Utilize peer tutors during class to work with struggling learners
English Language Learners	• Coordinate with ELL advisors to modify activities where appropriate • 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). • Additional resources and support for English as a Second Language students can be found at : http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf
Special Needs Learners	• Follow IEP modifications and work with special education teacher to make modifications and use Differentiated Instruction Activities. • Universal Design and Learning strategies and resources can be found at the following site: http://www.nj.gov/education/udl/

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.
- HSN.Q.A.1: Use units 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.
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.
- 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.
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems.
- 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.
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- 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.

HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Universal Gravitation

Unit Description:

The combination of Newton's Law of Universal Gravitation and Newton's 2nd Law will be applied to orbital mechanics describing the behavior of large planetary objects in our solar system. A historical context will be provided by discussing gravity and its role in the behavior of planetary systems. Gravity will serve as a launching point for a discussion of Kepler's Laws of planetary motion, and further applications of energy conservation.

Unit Duration: 1.5 weeks

Desired Results

Standard(s):

- 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)
- 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. (HS-PS3-1)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.
- 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.
  - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- PS3.C Relationship Between Energy and Forces
  - When two objects interacting through a field change relative position, the energy stored in the field is changed.

Understandings:

Students will understand that…

Newton's Law of Universal Gravitation is a useful model for predicting the behavior of artificial satellites as well as the planets and stars.

Successful models from the history of Physics can be used in contemporary science as long as the researcher is aware of the parameters of applicability of the model in use.

Essential Questions:

1. What is gravity?
2. How can "old" models still be in use hundreds of years after their development?
3. How does Newtonian mechanics describe the motion of planets and satellites?
4. What is a field?
5. In what way are forces and fields related?
6. Why in General Relativity considered the most sophisticated model of gravity?

Assessment Evidence

Performance Tasks:

Students will:

- Use Newton's 2nd Law and Universal Gravitation to analyze the behavior of planet systems.
- Recognize gravity as a "field force" and recognize the field nature of all forces.
- Describe the gravitational force inside and outside a uniform sphere, and calculate how the field at the surface depends on the radius and density of the sphere.
- Describe the motion of an object in orbit, and apply conservation laws to determine the object's velocity and location.

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work (including mathematical modeling)

In class and independent quizzes (appropriate topics include):

- Kepler's Laws
- Potential Energy Graphs

Independent work such as:

• Apply conservation laws to describe the potential and kinetic energy of objects in orbit.	• Completion of online and written problem sets • Partial and/or full formal laboratory reports Tests • Universal Gravitation

Benchmark:

Midterm Exam on all Mechanics Topics

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 13.(sections 13.1 – 13.6)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 13: Universal Gravitation

Topics:
Newton's Law of Universal Gravitation
Particle in a Gravitational Field
Kepler's Laws and the Motion of Planets
Gravitational Potential Energy

Suggested Activities: Phet Universal Gravitation Simulation, Phet Planetry Motion Simulation, Problem sets and video tutorials from Cengage WebAssign Chapter 13.
(Suggested Ch 13 Problem Set: 3,5, 9 11, 12, 16, 18, 21, 30, 31, 45, 65, 67, 69, 71)

Further Information regarding suggested activities:

- Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)

- Use of WebAssign Physics Assignments
  - Study Area activities for Chapter 13 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapters 13)
  - Students will read textbook content via e-book (Chapters 13)

- Online video tutorials are widely available to explain Universal Gravitation topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
  - Flipping Physics with Jonathan Thomas-Palmer

Resources:

Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

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"Next Time Questions" Paul Hewett, http://www.arborsci.com/next-time-questions

"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu.

Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)

Standard(s): 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.

4.0	**Students will be able to:** • Graphically show the Potential Energy of a satellite on a graph, and be able to show the infinite negative potential of a black hole.
3.0	**Students will be able to:** • Determine the criteria that causes elliptical orbits and generate a mathematical model accordingly
2.0	**Students will be able to:** • Determine the force that one spherically symmetrical mass exerts on another. • Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass. • Describe the gravitational force inside and outside a uniform sphere, and calculate how the field at the surface depends on the radius and density of the sphere. • Recognize that the motion does not depend on the object's mass; describe qualitatively how the velocity, period of revolution and centripetal acceleration depends upon the radius of the orbit; and derive expressions for the velocity and period of revolution in such an orbit. • Derive Kepler's third law for the case of circular orbits. • Derive and apply the relations among kinetic energy, potential energy and total energy for such an orbit. • State Kepler's three laws of planetary motion and use them to describe in qualitative terms the motion of an object in an elliptical orbit. • Apply conservation of angular momentum to determine the velocity and radial distance at any point in the orbit. • Apply angular momentum conservation and energy conservation to relate the speeds of an object at the two extremes of an elliptical orbit. • Apply energy conservation in analyzing the motion of an object that is projected straight up from a planet's surface or that is projected directly toward the planet from far above the surface.
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students

Advanced Learners	• 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. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system Provide challenge problems for advanced learners to solve

Struggling Learners	• 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). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via MyLab&Mastering) Utilize peer tutors during class to work with struggling learners
English Language Learners	• Coordinate with ELL advisors to modify activities where appropriate • 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). • Additional resources and support for English as a Second Language students can be found at : http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf
Special Needs Learners	• Follow IEP modifications and work with special education teacher to make modifications and use Differentiated Instruction Activities. • Universal Design and Learning strategies and resources can be found at the following site: http://www.nj.gov/education/udl/

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.

- HSN.Q.A.1: Use units 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.
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.
- 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.
- HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems.
- 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.
- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- 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.

HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Electrostatics

Unit Description:
The electromagnetic force is a fundamental force of nature. The behavior of charged particles and charged objects will be studied in depth. The importance of fields will be stressed as a major Physics model for describing electromagnetic behavior. Gauss' Law of Electricity and Coulomb's Law of electric force between charged particles will guide systems analysis.

Unit Duration: 4 weeks

Desired Results

Standard(s):

- 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)
- 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. (HS-PS3-1)
- 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. (HS-PS3-5)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.
- 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.
  - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- PS3.C Relationship Between Energy and Forces
  - When two objects interacting through a field change relative position, the energy stored in the field is changed.

Understandings:
Students will understand that…

The electromagnetic force is a fundamental force of nature that is classically described by Maxwell's Equations.

Electricity is a complex natural phenomenon that requires several basic Physics models to satisfactorily describe.

Thorough understanding of the concepts of force, field, potential, energy, charge is required to appreciate the sophistication of Maxwell's equations describing the electromagnetic interaction.

Essential Questions:

1. What is charge?
2. What is Coulomb's Law?
3. What is the nature of the Electric Field?
4. How are fields in involved in the application of forces to charged particles?
5. How can the electric field associated with a charged object be calculated?
6. What is electric potential?
7. What is the difference between potential and potential energy?
8. What are conductors and how do they behave?
9. What is a circuit?
10. What is the purpose of a capacitor?
11. What is potential difference?

Assessment Evidence

Performance Tasks:
Students will:

- Use Coulomb's Law to describe the electric force between charged particles.
- Use the concept of the electric field to describe the behavior of charged particles.

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions

• Use Calculus to determine the electric field associated with systems of charged particles. • Use Gauss' Law and the concept of flux to determine the electric field associated with uniform continuous charge distributions. • Develop an understanding of electric potential to simplify their analysis of electric systems.	• Peer tutoring • Lab work (including mathematical modeling) In class and independent quizzes (appropriate topics include): • Electric Fields • Gauss's Law • Electric Potential Independent work such as: • Completion of online and written problem sets • Partial and/or full formal laboratory reports Tests • Electrostatics

Benchmark:

Determine the electric field inside and outside a charged conductor

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 23, 24, 25.(sections 23.1 – 23.6, 24.1 – 24.4, 25.1 – 25.6)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 23: Electric Field

Topics:
Properties of Electric Charges
Charging by Induction
Coulomb's Law
Particle in an Electric Field
Electric Field of a Continuous Charge Distribution
Electric Field Lines
Suggested Activities: Phet Electric Field Lab Simulation, Conductive Ink on Carbon Paper to plot Electric Field Lines, and Equipotential Lines, Seeds in oil demo, Multiple Choice problems from prettygoodphysics.com, Problem sets and video tutorials from Cengage WebAssign Chapter 23.
(Suggested Ch 23 Problem Set: 3, 13, 15, 16, 17, 20, 23, 29, 34, 50, 51, 53, 54, 57, 67, 75, E-Fields: 37, 39, 42, 45)

Chapter 24: Gauss's Law

Topics:
Electric Flux
Gauss's Law
Gauss's Law with Various Charge Distributions
Conductors in Electrostatic Equilibrium
Suggested Activities: Previous years' AP test questions for the many examples of Gauss's Law type problems, Multiple Choice problems from prettygoodphysics.com, Problem sets and video tutorials from Cengage WebAssign Chapter 24.
(Suggested Ch 24 Problem Set: 2, 3, 4, 6, 7, 9, 10, 11, 12, 14, 15, 19, 24, 25, 26, 27, 29, 30, 33, 34, 35, 37, 45, 54, 57, 61, 65, 69)

Chapter 25: Electric Potential

Topics:
Electric Potential and Potential Difference
Potential Difference in a Uniform Electric Field
Electric Potential and Potential Energy Due to Point Charges
Relationship Between Electric Potential and Electric Field
Electric Potential Due to Continuous Charge Distributions
Electric Potential Due to a Charged Conductor
Suggested Activities: Previous years' AP test questions, especially 2016 Electric Field mapping question, Multiple Choice problems from prettygoodphysics.com, Problem sets and video tutorials from Cengage WebAssign Chapter 25.
(Suggested Ch 25 Problem Set: 3, 4, 5, 9, 10, 12, 16, 19, 23, 25, 37, 39, 43, 45, 50, 52, 53, 62, 64, 69)

Further Information regarding suggested activities:

- ❖ Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)

- ❖ Use of WebAssign Physics Assignments
  - Study Area activities for Chapter 23 - 25 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapters 23 - 25)
  - Students will read textbook content via e-book (Chapters 23 - 25)

- ❖ Online video tutorials are widely available to explain Electrostatics topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
  - Prettygoodphysics.com
  - Flipping Physics with Jonathan Thomas-Palmer

Resources:

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Next Generation Science Standards, http://www.nextgenscience.org/

New Jersey Student Learning Standards, www.nj.gov/education/cccs

"Next Time Questions" Paul Hewett, http://www.arborsci.com/next-time-questions

"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): Conservation of Energy and Energy Transfer o 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.	
4.0	**Students will be able to:** • Explain why Calculus is needed to determine the electric potential between two points on a line.
3.0	**Students will be able to:** • Describe how the Conservation of Energy can be applied to particles in a uniform, or non-uniform electric field to determine their energy and motion.
2.0	**Students will be able to:** • Describe the types of charge and the attraction and repulsion of charges • Describe polarization and induced charges • Calculate the electrical work done on a charge or use conservation of energy to determine the speed of a charge that moves through a specified potential difference • Calculate how much work is required to move a test charge from one location to another in the field of fixed point charges

	• Use integration to determine electric potential difference between two points on a line, given electric field strength as a function of position along that line • State the general relationship between field and potential, and define and apply the concept of a conservative electric field
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): Relationship Between Energy and Forces o When two objects interacting through a field change relative position, the energy stored in the field is changed.	
4.0	**Students will be able to:** • Determine a variable force on a particle due to an electric field, and compare the related motion to simple harmonic motion.
3.0	**Students will be able to:** • Identify situations in which the direction of the electric field produced by a charge distribution can be deduced from symmetry considerations
2.0	**Students will be able to:** • Calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field • Analyze the motion of a particle of specified charge and mass in a uniform electric field • Determine the electric potential in the vicinity of one or more point charges • Calculate by integration the electric field due to a wire, a thin ring, and a charged disk, and determine the force on a particle due to the electric field. • Derive expressions for electric potential as a function of position
1.0	**With help, partial success at level 2.0 content and level 3.0 content:**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• 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. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system Provide challenge problems for advanced learners to solve
Struggling Learners	• 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). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via MyLab&Mastering) Utilize peer tutors during class to work with struggling learners
English Language Learners	• Coordinate with ELL advisors to modify activities where appropriate

	• 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). • Additional resources and support for English as a Second Language students can be found at : http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf
Special Needs Learners	• Follow IEP modifications and work with special education teacher to make modifications and use Differentiated Instruction Activities. • Universal Design and Learning strategies and resources can be found at the following site: http://www.nj.gov/education/udl/

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.
- HSN.Q.A.1: Use units 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.
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.
- 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.
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- HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- 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.

HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Electric Circuits

Unit Description:
The rate of flow of charge is current; a closed pathway allowing for the movement of charge is a circuit. Physics models will be applied to the behavior of systems involving current and resistance will be introduced. Elementary circuit analysis will involve circuits comprised of batteries, resistors, and capacitors using Ohm's Law and Kirchhoff's rules of circuit analysis. In addition to steady state current systems, RC circuits will allow for a study of systems involving time variant current. The focus of study will be on direct current circuits.

Unit Duration: 4 weeks

Desired Results

Standard(s):

- 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)
- 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. (HS-PS3-1)
- Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). (HS-PS3-2)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.
- PS2.B: Types of Interactions
    - Forces at a distance are explained by fields permeating space that can transfer energy through spece. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- PS3.A: Definitions of Energy
    - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- 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.
    - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.

Understandings:
Students will understand that…
Circuits allow for the manipulation of moving charge and enable our modern technology to be based on electromagnetic energy.

While electric circuitry quickly becomes extremely complicated, Kirchhoff's Rules of circuit analysis are fundamentally applicable.

Essential Questions:
1. What is current?
2. What is resistance?
3. What role do batteries play in an electric circuit?
4. What is Ohm's Laws?
5. How do Kirchoff's Rules simplify circuit analysis?
6. How do circuit elements behave when wired differently (series versus parallel)?
7. What is a time variant current?
8. How do capacitors work and how do they create time variant currents?

Assessment Evidence

Performance Tasks:
Students will:
- Analyze elementary circuits using Ohm's Law and Kirchoff's Rules.

Other Evidence:
Daily informal and formal formative assessments of student activities, such as:
- Warm up problems/questions

- Recognize appropriate models to use when visualizing movement of charge through a circuit. - Analyze the behavior of different circuit elements wired in series and parallel. - Analyze time variant current associated with RC circuits. - Determine the electrical power available from electric circuits.	- Whiteboarding/problem solving sessions - Peer tutoring - Lab work (including mathematical modeling) In class and independent quizzes (appropriate topics include): - Capacitors and Dielectrics - Direct Current Circuits Independent work such as: - Completion of online and written problem sets - Partial and/or full formal laboratory reports Tests - Circuits

Benchmark:

Experimentally determine the time constant of an RC circuit

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 26, 27, 28.(sections 26.1 – 26.5, 27.1 – 24.5, 28.1 – 28.4)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 26: Capacitance and Dielectrics

Topics:
Capacitance
Calculating Capacitance
Combinations of Capacitors
Emergy Stored in a Capacitor
Dielectrics

Suggested Activities: Phet Capacitor Simulation, determine time constant for a variety of capacitors and resistors using Logger Pro™, Multiple Choice problems from prettygoodphysics.com, Problem sets and video tutorials from Cengage WebAssign Chapter 26.

(Suggested Ch 26 Problem Set: 2, 3, 5, 6, 7, 9, 13, 14, 22, 23, 24, 30, 32, 33, 37, 43, 45, 59)

Chapter 27: Current and Resistance

Topics:
Electric Current
Resistance
Drift Speed
A Model for Electrical Conduction
Resistance and Temperature

Suggested Activities: Vernier Circuit Board Lab (Ohm's Law), Multiple Choice problems from prettygoodphysics.com, Problem sets and video tutorials from Cengage WebAssign Chapter 27.
(Suggested Ch 27 Problem Set: 1, 8, 9, 12, 14, 16, 19, 27, 39, 45, 47, 61, 66)

Chapter 28: Direct Current Circuits

Topics:
Electromotive Force
Resistors in Series and Parallel
Kirchhoff's Rules
RC Circuits
Using Voltage and Current Measuring Devices

Suggested Activities: Build RC Circuit using breadboard with an LED light, Vernier Circuit Board Lab, determine time constant for a variety of capacitors and resistors using Logger Pro™, Multiple Choice problems from prettygoodphysics.com, Problem sets and video tutorials from Cengage WebAssign Chapter 28.
(Suggested Ch 28 Problem Set: 1, 2, 3, 5, 9, 13, 19, 22, 24, 28, 29, 30, 38, 39, 41, 44, 67, 75)

Further Information regarding suggested activities:

- ❖ Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of capacitors, current, resistance, and time constant.

- ❖ Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)

- ❖ Use of WebAssign Physics Assignments
  - Study Area activities for Chapter 26-28 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapters 26-28)
  - Students will read textbook content via e-book (Chapters 26-28)

- ❖ Online video tutorials are widely available to explain Circuits topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
  - Prettygoodphysics.com
  - Flipping Physics with Jonathan Thomas-Palmer

Resources:

Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

The College Board, www.collegeboard.org.
College Board AP Physics C Course Description: http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-c-course-description.pdf

McCulley, Frank. "The Physics Aviary." The Physics Aviary. N.p., 2017. Web. 28 June 2017
http://www.thephysicsaviary.com/

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Standard(s): Types of Interactions Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	
4.0	**Students will be able to:** • Use Calculus to derive current through a capacitor circuit as a function of time, for charging and discharging capacitors.
3.0	**Students will be able to:** • Use laboratory equipment to design an experiment that determines the time constant of an RC circuit, and compare it to actual values. • Design an experiment to test Kirchhoff's Rules • Explain how capacitor charge, and voltage change with adding/removing dielectrics • Explain how a dielectric increases capacitance
2.0	**Students will be able to:**

	• Determine the resistivity of a material and explain how changing its shape changes its resistance • Combine capacitors to determine the equivalent capacitance of a circuit • Use Kirchhoff's Rules to determine current through a circuit with multiple branches and batteries • Explain drift velocity and how it relates to current • Use internal resistance of a battery to determine the actual power supplied by the battery
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HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Magnetic Fields

Unit Description:
Moving charges are responsible for the physical phenomena traditionally classified as magnetism. Magnetic force and the magnetic field effect on moving charges will be studied. Magnetic effects on current carrying conductors will be studied. Electric effects and magnetic effects will be stressed as different aspects of electromagnetic interactions. The source of the magnetic field associated with common current configurations will be described using Ampere's Law which is introduced as a specialization of the Biot-Savart Law describing magnetic fields.

Unit Duration: 4 weeks

Desired Results

Standard(s):

- 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)
- 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)
- 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. (HS-PS3-1)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.
- PS2.B: Types of Interactions
  - Forces at a distance are explained by fields permeating space that can transfer energy through spece. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- PS3.A: Definitions of Energy
  - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- 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.

Understandings:
Students will understand that…

- All magnetic effects are the result of charge in motion.
- Magnetism and electricity are aspects of the electromagnetic interaction.
- Current carrying wires will experience magnetic effects just as permanent magnets do rendering redundant the model invoking magnetic poles

Essential Questions:

1. What causes magnetism?
2. How can magnetic fields be described using Biot-Savart and Ampere's Laws?
3. How are electricity and magnetism related?
4. What is the relevance of Gauss' Law of Magnetism?
5. How can Einstein's relativity be used to unify electricity and magnetism?

Assessment Evidence

Performance Tasks:
Students will:

- Recognize that all magnetic effects are the result of moving charge.
- Analyze the bahvior of charged particle moving through a magnetic field.
- Describe the magnetic field associated with commoncurrent configurations using Ampere's Law.

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

- Warm up problems/questions
- Whiteboarding/problem solving sessions
- Peer tutoring
- Lab work
-

• Use Biot-Savart Law to describe magnetic fields, specifically in the center of a circle of current. • Recognize the relative uselessness of the traditional model of magnetism using poles. • Recognize that relativity theory can be used to successfully describe magnetic effects as electric in nature.	In class and independent quizzes (appropriate topics include): • Right Hand Rule and Force on a particle in Magnetic Field • Torque on a Loop of Current Independent work such as: • Completion of online and written problem sets • Partial and/or full formal laboratory reports Test: • Magentic Fields, (including forces on wires in magnetic field, Ampere's Law, Magnetic Field of a Solenoid)

Benchmark:

Magnetic Solenoid Lab – design an experiment, collect and analyze data

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 29, 30.(sections 29.1 – 29.5, 30.1 – 30.6)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 29: Magnetic Fields

Topics:
Particle in a Magnetic Field
Motion of a Particle in a Magnetic Field
Applications of Magnetic Fields
Force on a Current Carrying Wire
Torque on a Current Loop

Suggested Activities: Right Hand Rule Practice sheets, Create a table displaying variables like m, q, r, v, and their impact on the motion of the particle in a circle, Demo: Youtube Veritasium: How magnets work, The Physics Aviary: Charge in a Magnetic Field (2 activities), Multiple Choice problems from prettygoodphysics.com using white boards, Problem sets and video tutorials from Cengage WebAssign Chapter 29.
(Suggested Ch 29 Problem Set: 2, 3, 4, 7, 11, 13, 18, 21, 23, 36, 35, 36, 39, 48, 51)

Chapter 30: Sources of the Magnetic Field

Topics:
The Biot-Savart Law
Magnetic Force Between two Parallel Conductors
Ampere's Law
Magnetic Field of a Solenoid
Gauss's law in Magnetism

Suggested Activities: Magnetic Solenoid Lab – measure magnetic field inside a solenoid (Slinky), Demo: force between two wires (apparatus located in class), Activity: Make a simple motor using a coil of wire, battery and small bar magnet. Multiple Choice problems from prettygoodphysics.com using white boards, Problem sets and video tutorials from Cengage WebAssign Chapter 30.
(Suggested Ch 30 Problem Set: 3, 6, 7, 9, 16, 21, 25, 31, 41)

Further Information regarding suggested activities:

❖ Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of magnetic field, direction and force of charged particle, creation of a magnetic field due to the flow of electricity, specifically through a solenoid.

❖ Use of online simulations (such as those found at The Physics Aviary) that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)

❖ Use of WebAssign Physics Assignments
  - Study Area activities for Chapter 29-30 (including practice questions, practice problems, and video tutor demonstrations)

- Teacher-selected questions and problems for independent work (Chapters 29-30)
- Students will read textbook content via e-book (Chapters 29-30)

❖ Online video tutorials are widely available to explain Magnetic Fields topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
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Resources:

Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

The College Board, www.collegeboard.org.
College Board AP Physics C Course Description: http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-c-course-description.pdf

McCulley, Frank. "The Physics Aviary." The Physics Aviary. N.p., 2017. Web. 28 June 2017 http://www.thephysicsaviary.com/

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Standard(s): Types of Interactions Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	
4.0	**Students will be able to:** • Use the Biot-Savart Law to predict the magnetic field at the center of a circular loop of current.
3.0	**Students will be able to:** • Explain a magnetic moment
2.0	**Students will be able to:** • Explain how magnetism and electric fields are related due to moving charges • Show how the magnetic force is a vector cross product of charge velocity and magnetic field strength • Describe the motion of a charged particle in a magnetic field and its resulting acceleration • Predict the motion of a loop of current in a magnetic field
1.0	**With help, partial success at level 2.0 content and level 3.0 content**
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HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Electromagnetism

Unit Description:
Michael Faraday's contribution to our understanding of electromagnetism is tremendous. Electromagnetic induction and the invention of the electric motor, electric generator and the transformer form the core of the unit. The resulting analysis of time variant magnetic fields lays the foundation for an introduction into the generation of electromagnetic energy waves and the use of magnetic fields to store energy in electric circuits.

Unit Duration: 3 weeks

Desired Results

Standard(s):

- 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)
- 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. (HS-PS3-1)
- Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). (HS-PS3-2)

Indicators:

- PS2.A: Forces and Motion: Newton's 2nd Law accurately predicts changes in the motion of macroscopic objects.
- PS2.B: Types of Interactions
  - Forces at a distance are explained by fields permeating space that can transfer energy through spece. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- PS3.A: Definitions of Energy
  - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- 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.
  - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.

Understandings:
Students will understand that…

- Electromagnetic induction allows the building of motors, generators, and transformers.
- Faraday's major contribution of electromagnetic induction will be studied in depth, including motional emf, function of motors, induced electric fields, RL and LC circuit analysis.
- Maxwell's equations provide a classical description of electromagnetic effects and are relativistic.

Essential Questions:

1. What is electromagnetic induction?
2. How do motors work?
3. What is motional EMF?
4. How is energy stored using magnetic fields?
5. How are electromagnetic waves generated?
6. How do the fundamental Physics principles apply to electromagnetic induction?

Assessment Evidence

Performance Tasks:
Students will:

Other Evidence:

Daily informal and formal formative assessments of student activities, such as:

• Use Faraday's law of electromagnetic induction as a basis for developing a functional electric motor. • State what must occur for an electric current to be indued in a loop fro a magnetic field. • Analyze motional EMF and induction. • Explain Lenz's Law and use it to predict the direction of induced currents. • Analyze RL and LC circuits. • Recognize the physics behind the generation of electromagnetic signals such as radio waves and TV signals.	• Warm up problems/questions • Whiteboarding/problem solving sessions • Peer tutoring • Lab work In class and independent quizzes (appropriate topics include): • Faraday's Law Independent work such as: • Completion of online and written problem sets • Partial and/or full formal laboratory reports Test: • Electromagnetic Induction and Inductors

Benchmark:

Demonstrate and explain inductance with bar magnet and coil of wire

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's Physics for Scientists and Engineers, 9th Ed. in chapters 31, and 32.(sections 31.1 – 31.5, 32.1 – 32.5)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 31: Faraday's Law

Topics:
Faraday's Law of Induction
Motional EMF
Lenz's Law
Induced EMF and Electric Fields
Suggested Activities: Demo: bar magnet thru coil generates current (apparatus in class), Phet Simulation – Faraday's Law, The Physics Aviary – 3 activities related to Magnetic Induction, Multiple Choice problems from prettygoodphysics.com using white boards, Problem sets and video tutorials from Cengage WebAssign Chapter 31.
(Suggested Ch 31 Problem Set: 1, 8, 9, 14, 17, 22, 26, 27, 36, 59, 60, 63, 83)

Chapter 32: Inductance

Topics:
Self-Induction and Inductance
RL Circuits
Energy in a Magnetic Field
Mutual Inductance
Oscillations in an LC Circuit
The RLC Circuit
Suggested Activities: Lab – Create an LC or RLC circuit using a breadboard, or with the Vernier Circuit Board, and determine time constant. Create a table comparing variables from SHM and an LC Circuit. Phet Simulations Circuit Construction. Multiple Choice problems from prettygoodphysics.com using white boards, Problem sets and video tutorials from Cengage WebAssign Chapter 32.
(Suggested Ch 32 Problem Set: 3, 6, 9, 13, 16, 20, 22, 24, 27, 31, 34, 39, 49, 55, 65)

Further Information regarding suggested activities:

- Use of Vernier LoggerPro™ and sensors for experimental development of the concepts of generating an electric field and resulting electric current by changing a magnetic field, time constants associated with inductors, current fluctuations due to inductors.

- Use of online simulations (such as those found at Colorado Phet Simulations that include lab-type activities as well as open-ended problems to solve (these can be used as in class "warm ups", computer "labs", independent work, or assessments.)

- Use of WebAssign Physics Assignments

- Study Area activities for Chapter 31-32 (including practice questions, practice problems, and video tutor demonstrations)
- Teacher-selected questions and problems for independent work (Chapters 31-32)
- Students will read textbook content via e-book (Chapters 31-32)

❖ Online video tutorials are widely available to explain Electromagnetism topics clearly. Examples of helpful sites are:
  - APPhysicslectures.com (stand-alone website, also available on YouTube)
  - Doc Schuster (YouTube)
  - APlus Physics with Dan Fullerton
  - Prettygoodphysics.com
  - Flipping Physics with Jonathan Thomas-Palmer

Resources:
Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

The College Board, www.collegeboard.org.
College Board AP Physics C Course Description: http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-c-course-description.pdf

McCulley, Frank. "The Physics Aviary." The Physics Aviary. N.p., 2017. Web. 28 June 2017
http://www.thephysicsaviary.com/

Next Generation Science Standards, http://www.nextgenscience.org/

New Jersey Student Learning Standards, www.nj.gov/education/cccs

"Next Time Questions" Paul Hewett, http://www.arborsci.com/next-time-questions

"PhET Interactive Simulations." PhET. University of Colorado, 2017. Web. 28 June 2017. https://phet.colorado.edu

Unit Learning Goal and Scale (Level 2.0 reflects a minimal level of proficiency)	
Standard(s): Types of Interactions 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.	
4.0	**Students will be able to:** • Explain the derivation of the energy stored in an inductor
3.0	**Students will be able to:** • Explain how an electric field is created due to a changing magnetic flux, (even without a wire) • Demonstrate and explain Eddy Currents • Derive the variable analogies between and LC Circuit and SHM
2.0	**Students will be able to:** • Explain magnetic flux and how it arises • Analyze systems with changing magnetic flux and predict the resulting current • Calculate the direction and magnitude of an induced current.
1.0	**With help, partial success at level 2.0 content and level 3.0 content**
0.0	**Even with help, no success**

Unit Modifications for Special Population Students	
Advanced Learners	• 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. • Provide opportunities for the advanced learner to act as a peer tutor during class time that involves student choice of activities. • Facilitate access to extensive enrichment activities using online learning management system Provide challenge problems for advanced learners to solve
Struggling Learners	• 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). • Facilitate access to extensive review and remediation activities through the learning management system and/or online text content (for example, use of Dynamic Study Modules and Tutorial problems available via MyLab&Mastering) Utilize peer tutors during class to work with struggling learners
English Language Learners	• Coordinate with ELL advisors to modify activities where appropriate • 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). • Additional resources and support for English as a Second Language students can be found at : http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf
Special Needs Learners	• Follow IEP modifications and work with special education teacher to make modifications and use Differentiated Instruction Activities. • Universal Design and Learning strategies and resources can be found at the following site: http://www.nj.gov/education/udl/

Integration of 21st Century Skills

Indicators:

The standards listed above and the performance tasks and activities that support them are infused with 21st Century Skills. The Level 3 skills listed in each of the Goals & Scales sections involve critical and creative thinking, communication and collaboration. The methods by which students attain these skills require that students practice multi-step problem solving, using technology to research and solve problems, and communicate results with their instructors and peers. The learning activities listed provide a mix of traditional classroom work and interactive, online experiences.

Science & Engineering Practices:
Asking questions and defining problems
Using Mathematics and Computational Thinking
Analyzing and Interpreting Data
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Cross-Cutting Connections:
Influence of Science, Engineering, and Technology on Society and the Natural World
Cause and Effect

Connections to Nature of Science:
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

- RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) to address a question or solve a problem.
- WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

Common Core State Standards Connections: Mathematics

- MP.2: Reason abstractly and quantitatively.
- MP.4: Model with mathematics.
- HSN.Q.A.1: Use units 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.
- HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA.SSE.A.1: Interpret expressions that represent a quantity in terms of its context.
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HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).

Unit Title: Modern Physics

Unit Description:
Relativity and The Standard Model of Quantum Mechanics represent the most sophisticated models in Physics today. In pairings, students will research an assigned topic in "modern physics" and prepare/present a 45 minute seminar summarizing the topic. A test will be administered based on the student presentations.

Unit Duration: 3 - 4 weeks

Desired Results

Standard(s):

- 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 (HS-PS4-3)

Indicators:

- 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)

Understandings:
Students will understand that…

- Together, Relativity Theory and The Standard Model, form our most sophisticated understanding of the behavior of the physical universe.
- Even so, the models have limitations in their usefulness, which continues to drive the pursuit of science for a most fundamental unification theory that will provide a complete, self consistent model of the behavior of the physical universe.

Essential Questions:

1. What is a unification theory?
2. What is relativity and what are its limitations in describing the behavior of nature?
3. What is The Standard Model and what are its limitations in describing nature?
4. What alternative models are proposed to expand/replace Relativity and The Standard Model?
5. What physical evidence exists to support these modern physics theories?

Assessment Evidence

Performance Tasks:
Students will:

- Recognize the physical relevance of Relativity theory.
- Recognize the physical relevance of The Standard Model of Quantum Mechanics.
- Recognize the need for continued research to identify more complete models to describe nature.
- Understand the importance of verifiable physical evidence to support models and develop theories.

Other Evidence:

Independent work such as:

- Work in groups of 1, 2 or 3 to prepare a 30 – 45 minute lecture on one topic in Chapter 39.
- Give the lecture.

Test:

- Modern Physics

Benchmark:

Exam on General Theory of Relativity, Special Theory of Relativity and The Standard Model

Learning Plan

Learning Activities: *The concepts in this unit are presented in Serway and Jewett's* *<u>Physics for Scientists and Engineers, 9th Ed.</u>* *in chapter 39.(sections 39.1 – 39.9)*
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

<u>Chapter 39: Relativity</u>
<u>Topics:</u>
Galilean Relativity
Michaelson-Morley Experiment
Einstein's Priciple of Relativity

Lorentz transformation Equations
Relativistic Linear Momentum
Relativistic Energy
General Theory of Relativity
Suggested Activities: Problem sets and video tutorials from Cengage WebAssign Chapter 39. No suggested problem set, as students are the "teachers/lecturers" and can assign problems as they see fit.

The Standard Model

Topics:
Matter Particles
Force and Carrier Particles
Particle Families
String Theory
Suggested Activities: Internet Research: The Standard Model, CERN, Fermilab. Other topics to research are: Heisenberg Uncertainty Principle, Quantum Mechanics, Shrodinger's Cat.

Further Information regarding suggested activities:

❖ Online video tutorials are widely available to explain Relativity and The Standard Model topics clearly. Examples of helpful sites are:
  - Doc Schuster (YouTube)
  - Don Lincoln from Fermilab

Resources:
Serway and Jewett, "Physics for Scientists and Engineers", 9th Ed., Cengage 2014

Unit Learning Goal and Scale (Level 2.0 reflects a minimal level of proficiency)	
Standard(s): 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.	
4.0	**Students will be able to:** • Use this wave/particle property of matter to explain the origins of Quantum Mechanics
3.0	**Students will be able to:** • Explain how large objects also have wave properties, but the wavlengths are so small that it is unnoticable
2.0	**Students will be able to:** • Explain how light, and all particles, have both wave and particle properties • It is through this property that the Heisenberg Uncertinty Principle arises • Explain the double slit experiment and how it relates to particle and wave properties
1.0	**With help, partial success at level 2.0 content and level 3.0 content**
0.0	**Even with help, no success**

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