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:	**Honors Physics**
Grade Level(s):	**11-12**

Duration:	*Full Year:*	**x**	*Semester:*		*Marking Period:*	

Course Description:	The honors physics course is offered to provide highly motivated students with an introduction to key topics in Newtonian Physics (forces and motion; circular motion and universal gravitation; work, energy, and conservation laws; rotational motion and equilibrium); Electricity and Magnetism (charge and static electricity, simple circuits, magnetic fields, and electromagnetism); Oscillatory Motion and Waves; and Light and Optics (electromagnetic radiation, geometric optics, and modern technologies based on the relevant phenomena). The course will provide opportunities for students these explore these topics in multiple ways and require that students show their understanding of content in multiple ways. Science and engineering practices and crosscutting concepts are woven through the content in the form of independent study, lab design and analysis, problem solving, and independent design projects. This course requires a strong working knowledge of algebra, geometry, and trigonometry. Additionally, due to the independent nature of many of the activities, students should possess good time management skills as well as a strong work ethic and a willingness to work with peers both in and out of the classroom.
Grading Procedures:	Tests 50% Quizzes 15%* Labs & Projects 20%** Independent Work & Problem Solving 15%*** **May include major and minor in class quizzes and minor online quizzes* ***This includes partial lab reports, full lab reports, short term projects, and long term independent and/or group projects.* ****This may include online problem sets, in class work on problems and questions, and other instructor selected activities.*
Primary Resources:	NJ Model Physics Curriculum Next Generation Science Standards NGSS New Jersey Student Learning Standards NJSLS <u>Physics: Principles With Applications</u>, 7^{th} ed. , Douglas C. Giancoli

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:	Shannon Hornibrook
Under the Direction of:	Dr. Patricia Hughes

Written: ________________________________

Revised: ________________________________

BOE Approval: ____________________________

Unit Title: Forces and Motion

Unit Description:

The motion of particles and objects at non-relativistic speeds can be described by the equations of kinematics and explained by Newton's laws of motion. In this unit, students will investigate the motions of particles/objects in a variety of ways, including student-designed lab activities, as well as predict the motion of particles/objects using Newton's laws of motion.

Unit Duration: 10 weeks

Desired Results

Standards:

- 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)
  - Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time.
  - Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.
  - Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations.
- Engineering Design: Optimizing the Design Solution (ETS1.C)
  - 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)
  - 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…

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

In the absence of outside influences the motion of a body is unchanged.

Changes in the state of motion of a body (acceleration).

Essential Questions:

1. What is an inertial frame of reference?
2. What does it mean to "move"?
3. How can motion be represented in different ways?
4. What is acceleration?
5. What does a vector represent?
6. How is vector mathematics similar to right triangle geometry?
7. How does the Law of Falling Bodies affect objects experiencing projectile motion?
8. What is a force?
9. What are the fundamental forces in nature?
10. What is the relationship between mass and inertia?
11. 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?
12. What is a Newton's third law force pair?
13. How can the forces on an object be represented visually and then be used to predict the behavior of that object?

	14. How are field forces different from contact forces? How are they alike? 15. What are examples of everyday forces, and how can they be incorporated in the analysis of a system? 16. 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? 17. How does the engineering processes factor into the final design of a device (such as that described above)?

Assessment Evidence

Performance Tasks:

Students will…

- 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, force, acceleration, mass, weight, normal force, tension, friction, inertia, gravity, apparent weight, action-reaction pair, equilibrium.
- Determine an unknown quantity within a system in the lab by analyzing the system, using relevant measurements and calculations.
- Analyze and interpret graphs of position vs time and velocity vs time for various motion.
- Calculate the components of a vector.
- Describe the conditions of projectile motion.
- Develop and apply an algorithm for the position of a projectile. (*Note: At the honors level, students are not expected to solve for initial launch angle)*
- 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.
- Select the appropriate trigonometric function to solve for an unknown side of a tringle, given the hypotenuse and an angle.
- Perform vector addition.
- Visualize relevant forces acting on an object.
- Draw and utilize a free body diagram and Newton's second law to predict the motion of an object that is being acted on by one or more forces.
- Draw an appropriate free body diagram to represent the forces acting on an object.
- Identify the "system of interest" and the "surroundings" for an object or particle.
- Identify sets of Newton's 3^{rd} law force pairs.
- Calculate the vector sum of a forces acting on an object and its resulting acceleration.
- Analyze a multiple body system.
- Describe the conditions of translational equilibrium.
- Evaluate statements made about forces acting on an object and identify errors in reasoning regarding forces acting on that object.
- With little input from the instructor, design and conduct an experiment, using available laboratory equipment, to test predictions about the motion of an object that is subject to one or more external forces.

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 Kinematics
- 2-D Kinematics
- Newton's Laws

Independent or Group Project *such as*:

- Problem-Based Learning Project (based on a complex projectile motion situation)
- Interview with a Physical Science Professional
- Designing and building a contraption that can be used to fire a projectile

Benchmarks: Lab: Newton's 2nd Law
Test: Forces and Newton's Laws

Learning Plan

Learning Activities:
The concepts in this unit are presented in Giancoli's Physics-Principles With Applications, 7th ed. in chapters 1-4.
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Kinematics (Motion):

1. One dimensional kinematics (straight-line motion without acceleration and with intervals of constant acceleration)
    a. Introduction to motion
    Topics:
    distance vs. displacement, speed vs. velocity, concept of vectors
    motion (dot) diagrams
    motion/kinematics graphs (distance-time, position-time, speed-time, velocity-time)
    Suggested Activities:
    Buggy Motion Lab, Vernier Graph Matching Lab/Activity, Spark Timer Tape Activity/Lab, Rolling Ball (Vernier Video Analysis), Moving Man (PhET), Distance & Displacement Challenge (Physics Aviary), Vector Scavenger Hunt, Problem sets & video tutorials from MyLab&Mastering Physics, Chapters 1 and 2

    b. Accelerated motion
    Topics:
    Motion/kinematics graphs (speed-time, velocity-time)- slope=acceleration
    Equations of kinematics for motion with constant acceleration
    Free fall acceleration
    Suggested Activities:
    Spark Timer Tape Activity/Lab, Graph Matching Challenge (Physics Aviary), Changing Velocity (Vernier Video Analysis), Moving Man (PhET), Acceleration Challenge (Physics Aviary), 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 & video tutorials from MyLab&Mastering Physics, Chapter 2

2. Two dimensional kinematics (focus on projectile motion)
    a. Digging deeper into vectors and vector math
    Topics:
    Resolving vectors into components
    Adding vectors
    Multiplying & Dividing Vectors
    Suggested Activities: Vector Addition (PhET), Problem sets & video tutorials from MyLab&Mastering Physics, Chapter 3

    b. Analyzing Projectile Motion
    Topics:
    Analysis of objects undergoing projectile motion (graphical and mathematical)
    -include non-zero angle launches, but limit "finding angles" to challenge (level 4) type problems, rather than "level 3" type problems.
    Objects under the influence of drag/air resistance in addition to gravity (conceptual)
    Suggested Activities:
    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), Projectile Motion Lab (student inquiry lab using available materials and probes), PBL Projectile Motion Challenge, Problem sets & video tutorials from MyLab&Mastering Physics, Chapter 3

Forces & Newton's Laws:

1. Introduction to Forces
    Topics
    Force as a vector quantity that is basically a push or pull
    Four fundamental forces

Free Body Diagrams, Defining system of interest
Suggested Activities: Open-ended discussion/Brainstorming- “What it a force?” “What are some forces we encounter every day?”, Forces in 1 Dimension (PhET)

2. Newton’s Laws
   Topics:
   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)

3. 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
   Suggested Activities: Force Table Lab (Resolution and addition of force vectors), Friction Lab (drag test, stopping distance or friction on incline), Newton’s 2nd Law Lab simulation (Physics Aviary), Half-Atwood Machine Lab, PBL “First Day on the Job” PBL Challenge (Stopping distance), Buoyancy Lab (PhET), Problem sets & video tutorials from MyLab&Mastering Physics, Chapter 4 *This lesson requires at least 1 week of instructional and practice time, as it is the culmination of learning all of the material to date in the course.*

Further Information regarding suggested activities:

- PBL Group Challenges: Students will be presented with a problem-based-learning challenge for either the “kinematics “material or the “forces” material, or both (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.
  Sources of inspiration for (and available for use) PBL challenges:
  - *Problem Based Learning for College Physics-A Website of Lifelike Activities (http://pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720)*
  - *Buck Institute for Education* (ex: Nasa’s “Weightless Wonder” and “Lunar Lander” PBL Challenge activities are indexed here.)

- 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 MyLab&Mastering Physics Activities/Assignments
  - Study Area activities for chapters 2-4 (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (chapters 1-4)
  - Students will read textbook content via e-book (chapters 2-4)

- Independent Project (Individual or Team): Teachers may choose from a variety of long term design and build challenge projects, which students would have the full marking period to complete.
  - Example: trebuchet/catapult for launching a projectile

Resources:

Giancoli, Douglas C. Physics: Principles with Applications, 7/E. Boston: Pearson, 2014. Print.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

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

Pearson. "Engage Students Effectively with Immersive Content, Tools, and Experiences." MyLab & Mastering | Pearson. Pearson, 2017. Web. 28 June 2017. <https://www.pearsonmylabandmastering.com/northamerica>.

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

"Why Project Based Learning (PBL)?" Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): HS PS2.A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. *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 analyze the motion of an object undergoing constant (non-"*g*") acceleration, with limited input from the instructor.
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 particular 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**

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): HS PS2.A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. *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 Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): HS PS2.A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects.	
4.0	**Students will be able to:** • Evaluate statements made about forces acting on an object and identify errors in reasoning regarding forces acting on that object. • Design and conduct an experiment, using available laboratory equipment, to test predictions about the motion of an object that is subject to one or more external forces (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. • Draw and utilize a free body diagram and Newton's second law to predict the motion of an object that is being acted on by one or more forces. • Draw an appropriate free body diagram to represent the forces acting on an object. • Calculate the vector sum of a forces acting on an object and its resulting acceleration. ○ Note: Systems will include those involving inclined planes, and multiple angled tension forces, in addition to those involving objects on flat surfaces.
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: force, acceleration, mass, weight, normal force, tension, friction, inertia, gravity, apparent weight, action-reaction pair, equilibrium, 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. • Visualize relevant forces acting on an object. • Describe the conditions of translational equilibrium.
1.0	**With help, partial success at level 2.0 content and level 3.0 content**
0.0	**Even with help, no success**

<table>
<tr><th colspan="2">Unit Learning Goal and Scale
(Level 2.0 reflects a minimal level of proficiency)</th></tr>
<tr><td colspan="2">Standard(s):
Forces and Motion:
ETS1.C Engineering Design: Optimizing the Design Solution
Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
ETS1.B Engineering Design: Developing Possible Solutions
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.</td></tr>
<tr><td>4.0</td><td>Students will be able to:
• Independently (with limited teacher input) work with a team to design, develop, build, and deploy a device that launches a specified projectile to hit a specified target (or reach a specified distance); the device meets all constraints provided, including cost, design considerations, etc.
• Analyze the performance of the device using video tracking software (ex- Vernier Logger Pro Video Analysis).
• Make recommendations for improvement on their device based on its performance.</td></tr>
<tr><td>3.0</td><td>Students will be able to:
• Employ the steps of the engineering process.
• Evaluate the types of devices for use in their task.
• Make detailed, scaled sketches in the planning phase of the project.
• Use computer simulations to test different variables in their design.
• Work within their team to finalize a design plan and to build the device.</td></tr>
<tr><td>2.0</td><td>Students will be able to:
• State the requirements of the project.
• Research different devices capable of launching a projectile.
• List different kinds of ballistic launch machines.
• Calculate the range of a generalized projectile.
• List the steps in the engineering process.</td></tr>
<tr><td>1.0</td><td>With help, partial success at level 2.0 content and level 3.0 content</td></tr>
<tr><td>0.0</td><td>Even with help, no success</td></tr>
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<table>
<tr><th colspan="2">Unit Modifications for Special Population Students</th></tr>
<tr><td>Advanced Learners</td><td>• 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.</td></tr>
<tr><td>Struggling Learners</td><td>• 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 avaible via MyLab&Mastering).
• Utilize peer tutors during class to work with struggling learners.</td></tr>
</table>

English Language Learners *(See http://www.state.nj.us/education/ modelcurriculum/ela/ELLSupport.pdf)*	• 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).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504 Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.	

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) in order 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 as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- 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: Circular Motion and Gravitation

Unit Description:

Newton's 2nd Law provides a basis for undersanding a variety of motions, including circular motion. Newton's Law of Universal Gravitation, along with Kepler's Laws of Planetary motion, describe the motion of planets and their satellites. Students will begin this unit with the basic concepts of circular motion, including centripetal acceleration and its potential causes. Orbits will be introduced in the context of Newton's thought experiment involving a faster and faster projectile fired from a cannon. The concept of a field will also be explored in the study of Universal Gravitation. (Escape velocities will be addressed later in the course, during the study of energy conservation.)

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)
- Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. (NGSS HS-PS2-4)
- Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. (NGSS HS ESS1-4)

Indicators:

- PS2.A: (Focus on circular and orbital motion) Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic object.
- PS2.B: (Gravitational force only) Types of Interactions: Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- ESS1.B: Earth and the Solar System: Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

Understandings:

Students will understand that…

Objects displaying circular motion are under the influence of an inward net force; the resulting acceleration (as defined in Newton's Second Law) is also inward, perpendicular to the object's velocity at any time.

Kepler's Laws of Planetary Motion were developed prior to Newton's Laws, and describe the motion of planets in our solar system.

Newton's Law of Universal Gravitation is an excellent model for gravity that proposed a mechanism for Kepler's Laws and is still widely used in modern society.

While Newton's Law of Universal Gravitation is a fundamental physical model, its limitations led Albert Einstein to develop General Relativity as a more sophisticated and widely applicable model of gravity.

Essential Questions:

- Why would an object or particle travel in a non-linear fashion?
- What is meant by "centripetal" acceleration and force?
- How do the following variables impact the amount of gravitational force between two objects: mass, distance between objects?
- What are some everyday examples of engineering that requires consideration of centripetal force/acceleration?
- How can Newton's Law of Universal Gravitation, together with Newton's Second Law be used to determine the magnitude of the gravitational field (and thereby, the magnitude of ***g***) for a specified planet?
- How can Newton's Law of Universal Gravitation, together with Newton's Second Law be used to mathematically describe the motion of an object in circular orbit?
- What are Kepler's Laws for orbital motion?
- How does Newton's Law of Universal Gravitation relate to Kepler's Laws?
- What are the limitations of Newton's Law of Universal Gravitation?

Assessment Evidence

Performance Tasks:

- Recognize and/or define the following terminology related to the analysis of an object that is moving in a circular or semi-circular path under the influence of one or more forces: centripetal acceleration, force, weight, normal force, tension, friction, inertia, gravity (universal gravitation), apparent weight, action-reaction pair, equilibrium, vector, vector component, coordinate system.
- Identify the direction of the net force on a body in circular motion as inward, toward the center of the circular path.
- Draw an appropriate free body diagram to represent the forces acting on an object.
- Determine an unknown quantity within a lab system that features an object in moving in a circular path, by analyzing the system, using relevant measurements and calculations.
- Draw and utilize a free body diagram and Newton's second law to predict the motion of an object that is being acted on by one or more forces, resulting in a centripetal acceleration.
- Discuss the reason for perceived "forces" in a non-inertial frame of reference and describe how those "disappear" when viewed from an inertial frame of reference.
- Identify an appropriate coordinate system by which to analyze the motion of and forces on an object moving in a circular path.
- Provide examples of everyday systems for which engineers must include centripetal forces/accelerations in their analysis in troubleshooting, planning and designing projects.
- Evaluate statements made about forces acting on an object that moves in a circular or semi-circular path, and identify errors in reasoning regarding forces acting on that object.
- Without the input of the instructor, design and conduct an experiment, using available laboratory equipment, to test predictions about the motion of an object moving in a circular path.
- Analyze the gravitational force acting on an object in circular orbit around a planet or star, in order to calculate orbital speed, orbital radius, or other variables associated with the system.
- Draw a diagram of an elliptical orbit and identify locations where the orbiting body moves at minimum and maximum speeds, based upon Kepler's laws and the law of Universal Gravitation.
- Sketch an appropriate graph of gravitational force vs. distance between objects, indicating an understanding of the inverse square proportionality of the relationship.

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):

- Circular Motion (topics could include basic circular motion, apparent weight, forces in a loop, etc.)
- Planetary Motion (Newton's Law of Universal Gravitation, Kepler's Laws)

Independent work such as:

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

Test

- Circular Motion and Planetary Motion

Independent or Group Project such as:

- Problem-Based Learning Project (based on a circular motion situation, ie. designing an exit ramp)

Benchmark: PBL Activity "Get Out- Designing a Highway Exit Ramp" (or similar task in which students must apply concepts in circular motion to a real world problem)

Learning Plan

Learning Activities:

The concepts in this unit are presented in Giancoli's Physics-Principles With Applications, 7th ed. in chapter 5.
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Circular Motion

Topics:
Uniform Circular Motion
Centripetal Acceleration
Use of Newton's 2nd law to analyze the motion of an object traveling in a circle
Unbanked curves
Non-uniform circular motion

Suggested Activities:
Ladybug Motion 2-D (PhET), Classic Circular Force Simulation, Car on a Turn, Force Normal on a Spinning Space Station (Physics Aviary), Centripetal Force Lab (using Vernier or analog equipment), "Get Out- Designing a Highway Exit Ramp" (PBL Circular Motion Challenge), Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 5

Planetary Motion

Topics:
Elliptical Orbits, Kepler's Laws
Newton's Law of Universal Gravitation
Gravitational Field Concept, Determining "**g**" using Universal Gravitation and Newton's 2nd Law

Suggested Activities:
Gravity Force Lab (PhET), Universal Gravity Simulations, Finding the Mass of a Planet (Physics Aviary), Circular Motion Self Test (Physcsi Aviary), Galileo 27-Orbiting Iris (PBL Univ. Grav. Challenge), Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 5

Further Information regarding suggested activities:

- PBL Group Challenges: Students will be presented with a problem-based-learning challenge for either the "circular motion" material or the "universal gravitation" material, or both (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit.
  Sources of inspiration for (and available for use) PBL challenges:
  - *Problem Based Learning for College Physics-A Website of Lifelike Activities (http://pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720)*
  - *Buck Institute for Education*
- Use of Vernier LoggerPro for video analysis of circular motion, which generates motion dot diagrams as well as motion graphs and data tables; 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 circular motion, centripetal forces, centripetal accelations, and angular quantities.
- 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 MyLab&Mastering Physics Activities/Assignments
  - Study Area activities for Chapter 5 (including practice questions, practice problems, and video tutor demonstrations).
  - Teacher-selected questions and problems for independent work (Chapter 5)

- Students will read textbook content via e-book (Chapter 5)

Resources:

Giancoli, Douglas C. Physics: Principles with Applications, 7/E. Boston: Pearson, 2014. Print.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

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

Pearson. "Engage Students Effectively with Immersive Content, Tools, and Experiences." MyLab & Mastering | Pearson. Pearson, 2017. Web. 28 June 2017. <https://www.pearsonmylabandmastering.com/northamerica>.

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

"Why Project Based Learning (PBL)?" Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

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

Standard(s):
HS-PS-2.A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic object. *(Focus on circular motion)*

4.0	**Students will be able to:** • Evaluate statements made about forces acting on an object that moves in a circular or semi-circular path, and identify errors in reasoning regarding forces acting on that object. • With limited input from the instructor, design and conduct an experiment, using available laboratory equipment, to test predictions about the motion of an object moving in a circular path.
3.0	**Students will be able to:** • Determine an unknown quantity within a lab system that features an object in moving in a circular path, by analyzing the system, using relevant measurements and calculations. • Draw and utilize a free body diagram and Newton's second law to predict the motion of an object that is being acted on by one or more forces, resulting in a centripetal acceleration. • Discuss the reason for perceived "forces" in a non-inertial frame of reference and describe how those "disappear" when viewed from an inertial frame of reference. • Identify an appropriate coordinate system by which to analyze the motion of and forces on an object moving in a circular path. *Note: Systems will include those involving non-uniform circular motion (changing speed) in addition to those involving uniform circular motion (constant speed). This will include vertical loops, pendulums, and planetary mechanics.*
2.0	**Students will be able to:** • Recognize and/or define the following terminology related to the analysis of an object that is moving in a circular or semi-circular path under the influence of one or more forces: centripetal acceleration, force, acceleration, mass, weight, normal force, tension, friction, inertia, gravity, apparent weight, action-reaction pair, equilibrium, vector, vector component, coordinate system. • Identify the direction of the net force on a body in circular motion as inward, toward the center of the circular path. • Draw an appropriate free body diagram to represent the forces acting on an object. • Calculate the vector sum of a forces acting on an object and its resulting acceleration. • Calculate the components of a vector. • Perform vector addition. • Visualize relevant forces acting on an object.
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): • PS2.B Types of Interactions: Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. *(Focus for this unit is on gravitational force only.)* • HS ESS1-4 Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	
4.0	**Students will be able to:** • Evaluate statements made about forces acting on an object moving in orbit about a point. • Derive the value of the Universal Gravitational Constant ("G") given orbital data.
3.0	**Students will be able to:** • Analyze the gravitational force acting on an object in circular orbit around a planet or star, in order to calculate orbital speed, orbital radius, or other variables associated with the system. • Draw a diagram of an elliptical orbit and identify locations where the orbiting body moves at minimum and maximum speeds, based upon Kepler's laws and the law of Universal Gravitation. • Sketch an appropriate graph of gravitational force vs. distance between objects, indicating an understanding of the inverse square proportionality of the relationship.
2.0	**Students will be able to:** • Identify the direction of the net force on a body orbit as inward, toward the center of path. • Draw an appropriate free body diagram to represent the forces acting on an orbiting body. • Visualize relevant forces acting on orbiting body. • Identify Kepler's Laws. • Identify Newton's Law of Universal Gravitation as one in which force is proportional to the inverse square of the distance between objects.
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 avaible via MyLab&Mastering). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/ modelcurriculum/ela/ELLSupport.pdf)*	• 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).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504 • Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.	

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) in order 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 as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- 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 and Momentum

Unit Description:

Physical systems can be described and analyzed in a variety of ways. One of the most powerful approaches is through the use of energy and/or momentum. In this unit, students will develop an operational definition of work, energy, power, impulse and momentum. They will further explore the conservation of energy and the conservation of linear momentum in a variety of ways, including traditional problem solving and student-designed laboratory investigations.

Unit Duration: 6 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 (obects). (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…

The work done on or by a system changes the energy "content" of that system, but does not result in a violation of conservation of energy.

Conservation Laws provide a powerful method by which systems can be analyzed.

Applications of the Law of Conservation of Energy and Conservation of Momentum have transformed society in many ways (collision safety, power generation, etc).

Essential Questions:

- What is "work", in the physics sense, and how is it related to energy?
- How can forces act to change the energy content of (ie- do work on) a system?
- Under what conditions can it be said that the mechanical energy *of a defined system* is conserved?
- How are Bernoulli's equation and the equation of continuity examples of applications of energy conservation?
- What is momentum?
- How can conservation of momentum be used in the analysis of a physical system?
- How is momentum of a system related to the motion of the center of mass of the system?
- How are Newton's Laws related to the conservation laws?
- How can an understanding of an application of the laws of conservation of energy and/or conservation of momentum be used to develop new devices/products that can benefit society?

Assessment Evidence

Performance Tasks:	**Other Evidence:**
• 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 the work done by a particular force acting through a particular distance (at a given angle with respect to displacement). • 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. • Use a force vs distance graph to infer the work done during a particular interval. • 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. • Quantify the amount of mechanical energy converted to thermal energy in a system that includes a dissipative force. • Examine a sample explanation of the energy changes in a system to find inaccuracies, and then correct the inaccuracies, providing justification for corrections. • Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. • State, verbally and via momentum equations, the impulse-momentum theorem. • State, verbally and via momentum equations, the law of conservation of momentum. • Calculate the 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. • 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. • Predict the post interaction velocities of particles or objects within a system, based on the type of interaction in which they are involved. • Design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time. • Design, build and demonstrate a device that minimizes the force on an object during collision OR a device that provides examples of how potential energy can be converted to kinetic energy.	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): • Work, Energy & Power • Conservation of Energy • Impulse & Momentum • 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 Tests • Work, Energy, Power & Conservation of Energy • Impulse, Momentum, Collisions, & Conservation of Momentum Independent or Group Project *such as*: • Problem-Based Learning Project (ie- “Bungie Jumper” Problem) • Design, build, and present an operational device that displays the conversion of energy from one form to another (ie- “Gravity Car” or “Mouse Trap Car”)* • Design, build, and present an operational device that displays the impulse-momentum theorem or conservation of momentum (ie- “Egg Drop”)* *Traditionally, these are long term (marking period-length) projects, and would be culminating activities for the marking period for which they best fit. For example, the Gravity Car project is best assigned for the second marking period, and would be demonstrated by students at the end of that marking period (rather than the end of this unit), as it also involves rotational mechanics considerations. It is not expected that student completions of two projects of this magntitude would be required during a unit/marking period.

Benchmark: Marking period 2 design and build project such as trebuchet, gravity car, mouse trap car, egg catcher, etc.
Midterm exam

Learning Plan

Learning Activities:
The concepts in this unit are presented in Giancoli's Physics-Principles With Applications, 7th ed. in chapter 5.
For each major topic/lesson, specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 6: Work & Energy

Topics:
Work
Potential Energy (Gravitational & Elastic)
Kinetic Energy
Conservative Forces
Non-Conserative Forces
Power
Conservation of Energy
Applications of Conservation of Energy (incl. Bernoulli and Continuity)

Suggested Activities:
Energy Skate Park (PhET), Speed from Work Graphs, Maximum Toss Height from Energy Conservation, Power Pulling Billy up a Hill, (Physics Aviary), Work-Energy Lab (using Vernier or analog equipment), "Net Work-KE", (Vernier Physics with Video Analysis), Bungee Jumper Problem (Design Challenge Lab activity), Gravity Car (Design and Build Project), Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 6

Chapter 7: Linear Momentum

Topics:
Momentum
Impulse
Conservation of Momentum
Collisions (Elastic & Inelastic)
Collisions in 2 Dimensions (as time permits)
Center of Mass

Suggested Activities:
Finding Speed from Impulse Graph, Collisions (Physics Aviary), "Center of Mass Motions", (Vernier Physics with Video Analysis), Impulse-Momentum Lab (using Vernier or analog equipment), Car Crash Lab/Activity (minimize collsion forces), Egg Drop Device (Design and Build Project), Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 7

Further Information regarding suggested activities:

❖ PBL Group Challenges: Students will be presented with a problem-based-learning challenge for either the "conservation of energy" material or the "conservation of momentum" material, or both (teacher may use existing materials or develop new challenges) to be completed by student groups over the course of a chapter or unit. Sources of inspiration for (and available for use) PBL challenges:
  - *Problem Based Learning for College Physics-A Website of Lifelike Activities (http://pbl.ccdmd.qc.ca/resultat.php?action=prob_tous&he=720)*
  - *Buck Institute for Education*

❖ Use of Vernier LoggerPro for video analysis of circular motion, which generates motion dot diagrams as well as motion graphs and data tables; 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 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 MyLab&Mastering Physics Activities/Assignments

- Study Area activities for Chapters 6 & 7,and part of 8 (including practice questions, practice problems, and video tutor demonstrations)
- Teacher-selected questions and problems for independent work (Chapters 6 & 7, 8.7 & 8.8)
- Students will read textbook content via e-book (Chapters 6 & 7, 8.7, 8.8)

Resources:

Giancoli, Douglas C. Physics: Principles with Applications, 7/E. Boston: Pearson, 2014. Print.

Laws, Priscilla W. Physics with Video Analysis: Activities for Classroom, Homework, and Labs Using Logger Pro Video Analysis Tools. Beaverton, OR: Vernier, 2009. Print.

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

Pearson. "Engage Students Effectively with Immersive Content, Tools, and Experiences." MyLab & Mastering | Pearson. Pearson, 2017. Web. 28 June 2017. <https://www.pearsonmylabandmastering.com/northamerica>.

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

"Why Project Based Learning (PBL)?" Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

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

Standard(s):
PS3.A: Definitions of Energy
Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

HS-PS3-B: 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.

ETS1.A: Defining and Delimiting an Engineering Problem

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 a 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): PS2.A: (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. ETS1.A: Defining and Delimiting an Engineering Problem	
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**

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 avaible via MyLab&Mastering). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• 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).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504 • Refer to page four in the Parent and Educator Guide to Section 504 to assist in the	

development of appropriate plans.	

Interdisciplinary Connections

Common Core State Standards Connections: ELA/Literacy

SL.11-12.5: Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1)
WHST.9-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3)

Common Core State Standards Connections: Mathematics

MP.2: Reason abstractly and quantitatively. (HS-PS3-1)
MP.4: Model with mathematics. (HS-PS3-1)
HSN.Q.A.1:Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1)
HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1)
HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1)
HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-2)
HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-2)
HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-2)

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: Rotational Mechanics

Unit Description:

Particles, objects and systems can be subjected to, and respond to not only unbalanced forces acting at their center of mass, but also to forces at some distance from a rotational axis. In the latter cases, these entities may experience unbalanced torques, which lead to rotational motion. In this unit, students will explore the links between translational motion and rotational motion, in cases of unbalanced torque. Examination of stability and systems in equilibrium will also occur in this unit.

Unit Duration: 4 weeks

Desired Results

Standards:

- 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)

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 mdels are applicable to all physical systems.

Rotational motion is analyzied using the same principles used to describe linear motion; differences arise in the details of the analysis.

The stability of a structure depends upon the location of its center of mass relative to its support base, a phenomenon that the designs of many natural and engineered structures are dependent upon.

Essential Questions:

- What is rotational motion?
- What are the angular analogs in angular mechanics for the linear quantities studied earlier in the curriculum?
- How does rotational motion differ from linear motion? How are the two connected?
- What are the physical drivers of rolling motion?
- How do Newton's Laws and the conservation laws apply to rotational motion?
- What are the conditions of equilibrium?
- What are some examples of natural structures and manmade structures that rely on location of center of gravity and the balance of forces and torques to maintain stability?
- What features make a structure more or less stable than others?

Assessment Evidence

Performance Tasks:

Students will…

- 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.
- Apply Newton's 2nd law to analyze a system or body experiencing one or more torques.

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):

- Angular Kinematics (using equations to solve for unknown angular quantities)
- Newton's 2nd law for rotation, torque and net torque calculations
- Conservated quantities associated with rotational motion

Independent work such as:

- Completion of online and written problem sets

• 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. • 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. • Apply the conservation of energy to a system in which one or more objects displays rotational motion. • Calculate the rotational kinetic energy of a rotating or rolling object. • Calculate the angular momentum of an object or system of objects. • Provide examples from nature of the conservation of angular momentum. • Apply the law of conservation of angular momentum to a system of objects in order to analyze the results of a collsion. • Use a graph of angular velocity vs. time to compare pre- and post- collision momenta for a rotating system. • Correctly predict the order of objects reaching the bottom of a frictionless ramp (sliding block, rolling solid ball, rolling cylinder) based on energy conservation. • Correctly predict final angular velocity (or other relevant quantity) for a system after a collision that involves angular momentum. • Correctly state the conditions for static equilibrium. • Provide examples of systems or objects in translational equilibrium, rotational equilibrium, and static equilibrium. • Determine an unknown quantity for a system in static equilibrium. • Design and build a device that demonstrates a system in static equilibrium. • Relate the concept of rotational equilibrium to balance and center of gravity. • Calculate and physically locate the center of gravity of an object or system.	• Partial and/or full formal laboratory reports • Participation in online discussion groups Test • Rotational Mechanics Independent or Group Project *such as*: • Design, build, and present an operational device that displays the conversion of energy from one form to another (ie- “Gravity Car” or “Mouse Trap Car”)* • Design, build, and present an operational device that displays the impulse-momentum theorem or conservation of momentum (ie- “Egg Drop”)* *These are repeated from the prior unit, as they would normally be completed over the course of these units.

Benchmarks: Lab: Torque and angular acceleration

Learning Plan

Learning Activities:
The concepts in this unit are presented in Giancoli's Physics-Principles With Applications, 7th ed. in chapters 8 and 9. For each major topic/lesson, suggested specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 8: Rotational Motion

Topics:
Angular quantities
Rolling Motion (rolling without slipping)
Toque
Rotational inertia
Newton's 2nd Law for rotation
Applications (solving problems in rotational dynamics)
Conservation laws applied to rotational motion/systems (rotational kinetic energy and angular momentum)
Vector quantities for rotational motion

Suggested Activities:
Torque (PhET), Net Torque, Moment of Inertia Pulley, (Physics Aviary), Torque & Angular Acceleration Lab, Conservation of Angular Momentum Lab/Demo (using Vernier or equipment), Rotating stool demo (conservation fo angular momentum), Downhill Race (rolling objects demo), Gravity Car (Design and Build Project), Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 8

Chapter 9: Static Equilibrium

Topics:
Conditions of Equilibrium
Solving Statics Problems
Aplications to Muscles & Joints

Suggested Activities:
Center of Gravity Activity (Locating COG via calculation, testing by balancing), Balancing Bird Demo, Bridge Lab (Balancing Torque, Equilibrium, hands-on lab),Scale Lab- Torque & Equilibrium (Physics Aviary), Suspension Bridge Lab(Physics Aviary), Center of Mass- Level 1 (Physics Aviary), Static Equilibrium-Level 1 (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 & video tutorials from MyLab&Mastering Physics- Chapter 9.1-9.4

Further Information regarding suggested activities:

- Use of Vernier LoggerPro and sensors for experimental development of Newton's 2nd Law for torque and angular acceleration.

- Use of online simulations (such as those found at PhET and 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 MyLab&Mastering Physics Activities/Assignments
    - Study Area activities for Chapters 8 & 9 (including practice questions, practice problems, and video tutor demonstrations)
    - Teacher-selected questions and problems for independent work (Chapters 8 and 9.1-9.4)
    - Students will read textbook content via e-book (Chapters 8 and 9.1-9.4)

Resources:

Giancoli, Douglas C. Physics: Principles with Applications, 7/E. Boston: Pearson, 2014. Print.

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

Pearson. "Engage Students Effectively with Immersive Content, Tools, and Experiences." MyLab & Mastering | Pearson. Pearson, 2017. Web. 28 June 2017. <https://www.pearsonmylabandmastering.com/northamerica>.

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

"Why Project Based Learning (PBL)?" Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

Unit Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): (HS PS2.A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects.	
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 Learning Goal and Scale *(Level 2.0 reflects a minimal level of proficiency)*	
Standard(s): HS PS2.A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects.	
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	
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 avaible via MyLab&Mastering). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• 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).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction

		• Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
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Interdisciplinary Connections

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HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1)
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HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-2)
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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: Electricity & Magnetism

Unit Description:

Electromagnetism forms the baseis of our modern technological society. Electric charge and the forces that arise between them as well as the concept of electric field are stressed. The related concept of electric potential and it application to simple, DC circuits is discussed, and simple circuits will be constructed and examined. Magnetism, including the Earth's magnetic field the concepts related to it are investigated. The production of electric current from changing magnetic flux and vice versa are explored at the conceptual level.

Unit Duration: 6 weeks

Desired Results

Standards:

- 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)
- Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. (HS-PS2-6)
- 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
  - Coulomb's Law provides a mathematical model to describe and predict the effect of electrostatic forces between distant objects.
  - 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.
  - Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

- 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…

- Charge is a fundamental characteristic of matter and is quantized.
- "Static Electricity" and electric fields occur in nature and are inherent in many natural phenomena at large and small scales.
- Manipulation of charges and fields provide the mechanisms for the development of modern technology.
- Fields are mathematical models that describe the phenomenon of forces working at a distance.
- Earth's magnetic field is thought to be caused by a dynamo within the core and interacts with incoming cosmic and solar particles.

Essential Questions:

- What is charge?
- How does an object become charged?
- What fundamental physics model describes the behavior of charged particles?
- What is the relationship between charges, distance, and electrostatic force?
- What is a field?
- How is electric current manipulated to perform work?
- Are charge and energy conserved in an electric circuit?
- Why are metals good choices for conductors in electronics?
- How can one mathematically analyze a DC circuit for quantities such as current, resistance, and power? How are these quantities related to one another?
- What are some physical considerations when planning household circuitry, and what are some dangers associated with faulty wiring?
- What is magnetism?
- What must be true of a charge in order for it to experience a magnetic force?
- What is the relationship between electric currents and magnetic fields?
- How is Earth's magnetic field thought to have originated, what has happened to it over time, and what effects does this field have on our technologies and society?
- How is electromagnetism used to make generators and motors?
- Historically how did scientists discover that electricity and magnetism are aspects of a single physical phenomenon?

Assessment Evidence

Performance Tasks:
Students will…

- Perform an investigation of the nature of charge.
- Describe the various methods of charging.
- Calculate total charge or number of charges for a given scenario.
- Calculate the net electrostatic force on a charge due to one or more other charges, and the resulting acceleration of that charge.
- Determine the location at which the net electrostatic force on a charge would be equal to zero.

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):

- Charges and Fields

• Provide examples in nature or in medicine for which electrostatics (forces or fields) play a significant role. • Sketch the electric field lines around a given charge. • Describe the change in electric potential energy as a result of movement within an electric field. • Calculate the current associated with a given amount of charge in a particular time interval. • Define current, charge, resistance, electric potential, and power. • Perform an investigation of Ohm's Law. • Analyze a basic, DC, circuit. • State Kirchoff's rules and describe each in terms of fundamental physical laws. • Compare and contrast series and parallel wiring of bulbs or resistors, providing examples of pros and cons of each. • Describe the Earth's magnetic field, including its probable origin and history. • Investigate the magnetic field around each of the following: a bar magnet, a solenoid, and a long thin wire. • Calculate the force on a charged particle moving through a magnetic field. • Design and construct a working, simple, motor from a battery, a magnet, and wire. • Describe the results of Oersted, Ampere and Faraday, including the significance of their work in modern society.	• Coulomb's Law • DC Circuit Analysis • Magnetic Fields • Magnetic Forces and Electromagnetism Independent work such as: • Completion of online and written problem sets • Partial and/or full formal laboratory reports • Participation in online discussion groups Tests • Electricity (Charge, Coulomb's Law, Fields, Circuits) • Magnetism

Benchmarks: Lab: Magnetic Field around a Solenoid OR Circuit Lab

Learning Plan

Learning Activities:

The concepts in this unit are presented in Giancoli's Physics-Principles With Applications, 7th ed. in chapters 16.1-16.8, 17.1-17.2,18.1-18.6, 19 (excluding 19.5 and 6), 20.1-20.10, and 21.1-21.5.
For each major topic/lesson, suggested specific activities are listed. Sources of activities can be found at the end of this section.

Charges & Fields

Topics:
What is charge?
How do objects become charged? (Conduction, tribocharging, induction and grounding)
Coulomb's Law
Electric Fields
Electric Potential Energy and Electric Potential (conceptual)

Suggested Activities:
Charging/Triboelectricity Lab ("sticky tape" lab or "electroscope charging" lab), VanDeGraff Generator (demo), Charged rod deflecting water stream (demo), Electroscope (demo/activity), Electric Field Apparatus (demo), PhET Activities: John Travoltage, Balloons & Static Electricity, Charges & Fields, Electric Field Hockey; Coulomb (Vernier Video Analysis Lab), Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 16

DC Circuits

Topics:
Current
Resistance & Resistivity
Power
Ohm's Law
Kirchoff's Rules (no necessary to apply to multiple battery situations; teach in context of charge and energy conservation)
Circuit Analysis (batteries and resistors/bulbs, capacitors not mandatory)

Suggested Activities:

PhET Activities: Battery-Resistor Circuit, Ohm's Law, Circuit Construction Kit; Physics Aviary: Resitance of Wire, Series Circuit, Parallel Circuit, Parallel in Series Circuit, Series in Parallel Circuit; Ohm's Law (Vernier Physics with Video Analysis), Vernier Circuit Lab, Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 17-18

Magnetism

Topics:

Magnetic Materials & Magnetic Domains
Magnetic Fields
Charges moving in Magnetic Fields
Field around a long, thin wire
Field around a solenoid
Oersted's experiment
Ampere's Law
Faraday's Law

Suggested Activities:

Investigating Magnetic Fields (iron filings over magnets, ferrofluid demos, etc), Inducing a Current with a Moving Magnet (Demo), Magnetic Force between 2 wires (demo), Measuring the Magnetic Field around a Magnet (Vernier Lab), Measuring the Magnetic Field of a Slinky (Vernier Lab), Build an Electromagnet (lab/activity), Build a Motor (lab/activity), PhET Activity: Faraday's Electromagnetic Lab; Physics Aviary: Magnetic Field from a Wire, Force on a Charge Moving in a Magnetic Field, Wind Turbine PBL Challenge (http://pblprojects.org/RSL/slide03.html) Problem sets & video tutorials from MyLab&Mastering Physics- Chapter 19

Further Information regarding suggested activities:

- Use of Vernier LoggerPro and sensors for Vernier Circuit lab and Magnetic Field around Magnet and Slinky labs.
- Use of Vernier Physics with Video Analysis for Coulomb Video Analysis Lab and Ohm's Law Video Analysis Lab.
- Use of online simulations (such as those found at PhET and 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 MyLab&Mastering Physics Activities/Assignments
    - Study Area activities for Chapters (including practice questions, practice problems, and video tutor demonstrations)
    - Teacher-selected questions and problems for independent work (Chapters 16-19)
    - Students will read textbook content via e-book (Chapters 16-19)

Resources:

Giancoli, Douglas C. Physics: Principles with Applications, 7/E. Boston: Pearson, 2014. Print.

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

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

"Why Project Based Learning (PBL)?" Project Based Learning | BIE. Buck Institute of Education, 2017. Web. 28 June 2017. <http://www.bie.org/>.

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

Standard(s):
HSPS2B. (Types of Interactions) Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.

4.0	**Students will be able to:**

	• Predict the direction and the magnitude of the acceleration due to the net force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field.
3.0	**Students will be able to:** • Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
2.0	**Students will be able to:** • Describe the relationship between distance and force as an inverse square relationship. • Connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. • Calculate the net electric force that results from the interaction of several point charges. • Construct a free body diagram representing the forces acting on a charged particle. • Perform a force summation to analyze the total force on a charged particle. • Define charge, conservation of charge, and 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):
HSPS2-B: 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:** • Construct a simple, working motor from a battery, wire, and a magnet.
3.0	**Students will be able to:** • Use laboratory equipment to collect data on the magnetic field strength around a current-carrying solenoid. • Conclude that magnetic field is directly proportional to the current through a wire. • Calculate the field near a current carrying wire using Ampere's Law. • Explain why currents running in opposite directions repel while those running in the same direction attract.
2.0	**Students will be able to:** • Describe Oersted's experiment that demonstrated that there is a connection between current and magnetic field. • Use a compass to observe a changing magnetic 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 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 avaible via MyLab&Mastering). • Utilize peer tutors during class to work with struggling learners.
English Language Learners (See *http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf*)	• 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).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504 • Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.	

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. (HS-PS2-1)

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

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

Common Core State Standards Connections: Mathematics

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

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

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

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

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

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

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

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

HSA.CED.A.4: Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1)

HSF-IF.C.7: Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. (HS-PS2-1)

HSS-IS.A.1: Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

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: Oscillatory Motion and Waves

Unit Description:

From seismic waves to sound waves, from gamma radiation to microwaves, periodic motion and oscillations appear throughout nature. In this unit, students build upon prior knowledge of wave behavior (for example, general wave characteristics and the wave speed equation) and their recent studies of forces and motion to develop a higher level of understanding of oscillatory motion and waves. Waves on strings and in air columns will be observed and measured, and sound waves will be studied at some depth, due to their pervasive presence in the human experience. Students will be briefly reminded about the wave nature of light and the general behaviors of waves as they interact. Electromagnetic radiation will be studied in greater depth in the next unit.

Unit Duration: 4 weeks

Desired Results

Standards:

- 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)
- Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (HS-PS4-1)
- Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (HS-PS4-5)

Indicators:

- PS2.A: Forces and Motion: Newton's 2^{nd} 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.
- PS4.A: Wave Properties
  - The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
  - Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.
- PS4.C: Information Technologies and Instrumentation

Understandings:
Students will understand that…

- While harmonic motion is period, not all periodic motions are harmonic.
- Oscillatory motion is common throught nature in both macroscopic and microscopic systems.
- Simple harmonic motion is one (idealized) form of oscillatory motion that can be modeled. mathematically via data analysis derived from relatively simple experiments.
- Waves and particled behave in fundamentally different ways.
- Waves area a means for transferring energy without a corresponding transport of matter.
- Wave mechanics describe the behavior of sound and light.
- Waves can be used to transmit information.

Essential Questions:

- What causes oscillatory motion?
- What are some natural phenomena that are oscillatory in nature?
- What characteristics define and describe simple harmonic motion?
- What physical factors determine the period of harmonically oscillating systems?
- What is a wave?
- What is the relationship between simple harmonic motion and wave behavior?
- What are the distinguishing characteristics of the types of waves?
- What aspect of a wave has the greatest effect on the energy carried by that wave?
- How does the human ear respond to the energy of a sound wave?
- What are some natural phenomena that are propagated via waves?

Assessment Evidence

Performance Tasks:
Students will…

- Identify the portion of a graph force applied to a spring and its resulting stretch for which the spring dispays Hookean behavior.
- Provide examples of harmonic motion.
- Calculate the frequency and period of an oscillator.
- Design and conduct an experiment to determine the factors that affect the period/frequency of an oscillator (systems to be analyzed can include a simple pendulum, spring-mass oscillator, and an intertial mass balance.
- Use video analysis to study and graph the motion of an oscillator.
- Identify the following locations on a position-time graph for a harmonic oscillator: amplitude, period, zero velocity, maximum speed, minimum/maximum acceleration, minimum/maximum restoring force, minimum/maximum kinetic energy, and minimum/maximum elastic potential energy.
- Apply the concept of energy conservation to an oscillator to determine various values associated with its motion.
- Provide technological and every day examples of systems that use harmonic motion (simple, damped, and driven) to accomplish a goal.
- Use a long spring to physically create examples of transverse and longitudinal waves.
- Determine the speed of a wave in various media (spring, string, sound wave in air, etc.) through experimentation and through problem solving.
- Investigate the behavior of a mechanical wave at a boundary.
- Determine the minimum and maximum amplitude for waves or pulses interfering constructively and destructively.
- Calculate the energy transmitted by a mechanical wave.

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):

- Simple harmonic motion
- Waves & wave interference
- Sound

Independent work such as:

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

Tests

- Simple Harmonic Motion
- Waves & Sound

- Perform an experiment by which the speed of sound in the classroom can be measured, and analyze the results for accuracy and precision.
- Sketch standing waves on a string to represent various harmonics; identify the nodes and antinodes.
- Sketch standing waves on in an air column to represent various harmonics; identify the nodes and antinodes.
- Use the wave speed equation along with understanding of harmonics to calculate any of the following features: frequency of the wave, harmonic number, length of the string (or air column), and speed of the wave.
- Explain how musical instruments capitalize on the production and amplification of harmonics.
- Demonstrate that the intensity of a wave is inversely proportional to the square of the distance from the source to the receiver.
- Calculate the intensity of a wave at a particular location.
- Determine the intensity level (in dB) of a wave.
- Describe, in terms of frequency and wave behavior, the way in which the human ear acts to receive sound and how that is perceived (pitch and loudness).
- Describe the perceived change in frequency when a source, observer, or both are in relative motion, as compared to when there is no relative motion between them.
- Calculate the observed frequency due to a Doppler shift.
- Provide examples and basic explanations of how wave behavior is used in modern technologies such as Doppler radar, Ultrasound imaging, sonar, cosmic microwave background radiation, etc.

Benchmarks: Lab: Simple Harmonic Oscillator OR Lab: Speed of Sound

Learning Plan

Learning Activities:

The concepts in this unit are presented in Giancoli's Physics-Principles With Applications, 7th ed. in chapters 11 & 12. For each major topic/lesson, suggested specific activities are listed. Sources of activities can be found at the end of this section.

Chapter 11: Oscillation & Waves

Topics:
Hooke's Law
Characteristics of Simple Harmonic Motion
Energy in Simple Harmonic Motion
Simple Pendulum
Damped Harmonic Motion
Forced Oscillations & Resonance
Wave Motion
Types of Waves
Energy Transfer via Waves
Interference
Standing Waves

Refraction
Diffraction

Suggested Activities:
Labs: Hooke's Law, Spring-mass oscillator, simple pendulum, inertial mass balance, Oscillations (Video Analysis); Virtual Labs: Masses & Springs (PhET), Pendulum (PhET), Wave on a String (PhET), Wave Interference (PhET), Energy of a Displaced Pendulum (Physics Aviary), Wave Properties from Graph (Physics Aviary), Interfering Waves (Physics Aviary), Reflecting Waves (Physics Aviary)

Chapter 12: Sound

Topics:
Characteristics of sound
Intensity and intensity level
Sources of Sound (strings and air columns)
Interference & Beats
Doppler Effect
Applications of sound (sonar, ultrasound, imaging)

Suggested Activities:
Labs: Finding the Speed of Sound in Air (echo method and/or resonance method), Sound Waves & Beats; Standing wave demo, Doppler Effect Demo, Resonance Tube (Physics Aviary), Speed of Wave on a String (Physics Aviary), Speed of Sound (Physics Aviary), Intensity (Physics Aviary), Doppler Effect (Physics Aviary); Sound (PhET), Doppler Effect 1 and 2 (Physics with Video Analysis)

Further Information regarding suggested activities:

- Use of Vernier LoggerPro and sensors for Hooke's Law lab, spring-mass oscillator lab, and simple pendulum lab
- Use of Vernier Physics with Video Analysis for Oscillations Video Analysis lab and Doppler Effect 1 and 2 labs
- Use of online simulations (such as those found at PhET and 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 MyLab&Mastering Physics Activities/Assignments
    - Study Area activities for Chapters 11 and 12 (including practice questions, practice problems, and video tutor demonstrations)
    - Teacher-selected questions and problems for independent work (Chapters 11 and 12)
    - Students will read textbook content via e-book (Chapters 11 and 12)

Resources:

Giancoli, Douglas C. Physics: Principles with Applications, 7/E. Boston: Pearson, 2014. Print.

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

Pearson. "Engage Students Effectively with Immersive Content, Tools, and Experiences." MyLab & Mastering | Pearson. Pearson, 2017. Web. 28 June 2017. <https://www.pearsonmylabandmastering.com/northamerica>.

"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):
HS-PS3.B: 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.

4.0	**Students will be able to:** • Design and conduct an experiment to analyze the motion of harmonic oscillator and to develop an mathematical model to represent that motion.
3.0	**Students will be able to:**

	• Use the equation for the position (in terms of time) for simple harmonic oscillators in order to be able to determine the amplitude and frequency of the motion. • Predict the speed of a mass oscillating on a spring at a particular position, given the mass, the spring constant the amplitude, and the current position of the mass.
2.0	**Students will be able to:** • Identify the variables for mass, time, spring constant, amplitude, position, kinetic energy, and elastic potential energy. • Use the equations for period/frequency of an oscillator to determine selected quantities. • Locate (on a position-time graph) the amplitude, period, positions of max/min KE, PEspring, acceleration, force and speed.
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):

HS-PS4.A: Wave Properties: The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.

4.0	**Students will be able to:** • Design an experiment by which a sound wave can be produced and then analyzed in such a way as to determine the wavelength of the fundamental frequency for the system.
3.0	**Students will be able to:** • Determine the speed of a wave on a string under tension. • Calculate the possible harmonics for the speed of a wave on a string. • Describe the process by which the wave produced on a string transfers energy to set air (or other molecules) into oscillation, and then how that resulting sound wave is transformed into another mechanical wave in the human ear.
2.0	**Students will be able to:** • Use the wave speed equation to calculate wavelength, frequency, or speed. • Draw and label the parts of a wave. • Draw and label a particular standing wave. • Give examples of mechanical waves. • Compare and contrast mechanical and electromagnetic waves. • Compare and contrast longitudinal waves and transverse waves, giving examples of each.
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0.0	**Even with help, no success**

Unit Modifications for Special Population Students

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English Language Learners *(See http://www.state.nj.us/education/ modelcurriculum/ela/ELLSupport.pdf)*	• 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).
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HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1)

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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
Obtaining, Evaluating, and Communicating Information

Cross-Cutting Connections:
Interdependence of Sience, Engineering and Technology
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: Electromagnetic Radiation and Optics

Unit Description:

In this unit of study, students will apply their understanding of wave properties to investigate how light and other forms of electromagnetic radiation behave and how it can be used to transfer information across long distances, store information, and used to investigate nature on many scales. Students will research models of EM radiation as changing electrical and magnetic fields (propagating as waves) and as particles (photons). Students will demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (Adapted From NJ Model Curriculum- High School Physics) Light will also be studied in the context of physical and geometric optics both through hands on lab work and simulations.

Note: The depth to which the content will be presented and investigated will depend largely on the time available, as some time will be allotted for final exams, exam review, and state testing. At minimum, problems, lab work, and simulations will be done related to geometric optics, and the technological (information transmission, storage, devices, etc) material could be addressed via student projects, researched and prepared outside of class time.

Unit Duration: 4 weeks

Desired Results

Standards:

- Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (HS-PS4-1)
- 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)
- Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. (HS-PS4-4)
- Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (HS-PS4-5)
- Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. (HS-ETS1-1)

Indicators:

- PS3.A: Definitions of Energy
  - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- PS4.A: Wave Properties
  - The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)
  - Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2),(HS-PS4-5)
  - Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.
- 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.

- PS4.C: Information Technologies and Instrumentation
  - Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.
- 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.
  - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Understandings:
Students will understand that…

- Waves can be used to transmit information.
- Information can be digitized.
- Waves transmit energy, which can be both helpful and harmful, depending on their interactions with matter.
- Light exhibits both wave and particle characteristics.
- A wave model of light includes a description of light as a portion of the electromagnetic spectrum.
- Visible images can be formed by both reflection and refraction.
- Light can be used to transmit information.
- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.
- 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.
- A wave model or a particle model (e.g., physical, mathematical, computer models) can be used to describe electromagnetic radiation—including energy, matter, and information flows—within and between systems at different scales.
- A wave model and a particle model of electromagnetic radiation are based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Essential Questions:

- What is light?
- What scientific models are used to describe light?
- How does light behave at boundaries between different materials?
- How can the images formed by lenses/mirrors be predicted?
- How are lenses used to solve problems? (ie- corrective lenses, tech. applications like telescopes and microscopes, etc)
- How does the eye function as a lens?
- What is the science underlying fiber optics?
- How is light (and other electromagnetic radiation) used to transmit information?
- How does the behavior of light explain the formation of rainbows, mirages, and other optical phenomena?

Assessment Evidence

Performance Tasks:

Students will…

- Describe light as one part of the electromagnetic spectrum, all of which can be described using a wave model and a particle model.
- Provide examples of evidence for light's wave nature.
- Provide examples of evidence for light's particle nature.
- Discuss the contribution of Newton, Huygens, Young, Maxwell, Michelson, and Einstein in the evolution of scientific models for the behavior of light.
- Define/describe reflection, refraction, and diffraction of light pictorially and verbally.
- Conduct an experiment to analyze the effect of distance from a light source on the intensity of light at a particular location.
- Calculate angles of incidence or refraction (or indices of refraction) for light moving between media, using Snell's Law.
- Using ray diagrams, predict the images formed by mirrors and lenses, and combinations of lenses.
- Perform experiments to determine the relationship between focal length, object distance, and image distance for a lens.
- Analyze an image of the human eye and identify the lens, retina, pupil, and iris, and make analogies to other optical systems.
- Discuss the use of total internal reflection in fiber optics technologies.
- Provide examples of interference patterns in nature and give a basic explanation for their occurrence.
- Present and describe examples of ways in which diffraction of EM radiation is used in scientific research and medical technologies.

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):

- Reflection, refraction, and dispersion (including Snell's law and indices of refraction)
- Ray diagramming for mirrors and lenses, thin lens equation, applications of mirrors, lenses, and total internal reflection
- Diffraction (concept and applications- mathematical analysis only if time allows)

Independent work such as:

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

Test

- (if time permits) Electromagnetic Radiation and Optics

Independent/Group Project

Suggestions

- Research, development, and presentation of an application of refraction, reflection, or diffraction; here are some examples of sources of problem-based learning projects:
  - Design your own spectrograph:
    https://www.teachengineering.org/activities/view/cub_spect_activity8
  - Acoustic Mirrors:
    https://www.teachengineering.org/activities/view/gat_mirrors_activity1
- Research and present a modern physic topic (one dealing with light, EM radiation, etc. would be most topical, but other topics might include special and general relativity, uncertainty principle, etc.)

Benchmarks: Independent Project

Final Exam

Learning Plan

Learning Activities:
The concepts in this unit are presented in selected sections of Giancoli's Physics-Principles With Applications, 7th ed. in chapters 22, 23, 24, 25 and 27.
For each major topic/lesson, suggested specific activities are listed. Sources of activities can be found at the end of this section.

Electromagnetic Radiation

Topics (focus on conceptual)
Production of EM Waves
Light as an EM Wave
Measuring the Speed of Light
Wireless communication

Suggested Activities:
Radio Waves & EM Fields (PhET),

Geometric Optics

Topics
Reflection, Refraction and Dispersion of light
Snell's Law and Index of Refraction
Ray diagramming for mirrors and lenses (mainly lenses)
Optical systems (applications such as corrective lenses, telescopes, microscopes)

Suggested Activities:
Investigating mirrors and lenses (student discovery activity, informal), Refraction of Light Lab (Physics Aviary), The Way a Mirror Works Labs (Physics Aviary), Image from a Converging Lens (Physics Aviary), Snells Law Lab (hands on, using refraction blocks and tanks, rulers, and protractors), Snells Law with Video Analysis (Physics with Video Analysis), Fiberoptics PBL Challenge (http://pblprojects.org/RSL/slide03.html)

Physical Optics (brief coverage of topics- very little time will be allotted as final exams will be imminent at this point in the year, emphasize applications of these concepts more than a mathematical treatment of each of them)

Topics:
Huygens' Principle & Diffraction
Young's Double Slit Interference
Visible Spectrum and Dispersion
Diffraction gratings, spectrometry and spectroscopy, thin films
Interferometry (also relate to LIGO)
Polarization

Suggested Activities (as time permits):
Light- Brightness and Distance (Vernier Lab using light sensors), Diffraction of Light (Physics Aviary), Diffraction Grating Lab (Physics Aviary), Photoelectric Effect Lab (Physics Aviary), Design Your Own Spectrograph (PBL Challenge from TeachEngineering.org)

- Use of Vernier LoggerPro and sensors for Light Brightness and Distance Lab.
- Use of Vernier Physics with Video Analysis for Snell's Law with Video Analysis Lab.
- Use of online simulations (such as those found at PhET and 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 MyLab&Mastering Physics Activities/Assignments
  - Study Area activities for Chapters 22, 23, 24, 25 and 27 and (including practice questions, practice problems, and video tutor demonstrations)
  - Teacher-selected questions and problems for independent work (Chapters 22, 23, 24, 25 and 27)
  - Students will read textbook content via e-book (instructor selected sections from 22, 23, 24, 25 and 27)

Resources:

"Designing a Spectroscopy Mission - Activity." Www.teachengineering.org. Regents of the University of Colorado, 2008. Web. 20 July 2017. <https://www.teachengineering.org/activities/view/cub_spect_activity8>. Contributed by Laboratory for Atmospheric and Space Physics (LASP), University of Colorado Boulder

Giancoli, Douglas C. Physics: Principles with Applications, 7/E. Boston: Pearson, 2014. Print.

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

Pearson. "Engage Students Effectively with Immersive Content, Tools, and Experiences." MyLab & Mastering | Pearson. Pearson, 2017. Web. 28 June 2017. <https://www.pearsonmylabandmastering.com/northamerica>.

"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): *This section deals with reflection and refraction of light.*

HS-PS-4A: Wave Properties: The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

4.0	**Students will be able to:** • Plan and carry out an investigation into the relationship between light intensity and distance from a light source, with little or no input from instructor, or… • Plan and carry out an investigation into the mathematical relationship between image distance, object distance, and focal length, with little or no input from instructor.
3.0	**Students will be able to:** • Predict (mathematically calculate) the angle of refraction given the angle of incidence for a ray of light moving through a particular set of materials. • Predict the nature of images (location, type, orientation, and size) produced by various types of lenses or mirrors, using ray diagrams. • Use lab equipment (glass block, acrylic block and/or water tank) to determine the index of refraction for a given object. • Explain the conditions for total internal reflection and how it is used in telecommunications • Investigate multiple lense/mirror combinations in use in various areas of science (microscopes, telescopes, etc).
2.0	**Students will be able to:** • Define the following terms in relation to physics: *reflection; plane mirror; spherical mirror; law of reflection; refraction; index of refraction; Snell's Law; total internal refection; magnification; real image; virtual image; converging lense/mirror; diverging lense/mirror; radius of curvature; focal length; ray diagram.* • Determine the index of refraction for a material. • Determine the angle of reflection for an incident ray. • State the relationship between density and the speed of light in a material. • Predict the bending of light in general terms (toward/away from the normal) based on Snell's Law • Classify various types of lenses or mirrors. • Classify the focal length of lenses and mirrors as positive or negative based on the type of lense/mirror. • Use the lens equation to locate an image. • Categorize images as real or virtual based on the lens equation. • Describe spherical mirrors. • Describe the use of ray tracing to location and identify images.
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): *This section deals with the nature of light and the EMS.*

HS-PS-4B: Electromagnetic Radiation: Electromagnetic radiation 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-PS-4C: Information Technologies and Instrumentation: Multiple technologies based on the understanding of waves and their interactions with mater are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

4.0	**Students will be able to:** • Present (time permitting) their digital product to the class in a brief lesson about their topic; inclusion of a physical model of some aspect of the topic would indicate level 4 learning. • Peer review the digital artifacts produced by other students. • Use the information presented by classmated in order to compare and contrast the different technologies in terms of their scientific bases, uses, etc.
3.0	**Students will be able to:** • Research a modern EM radiation/wave technology used in research/medicine/communications. • Produce a high quality digital presentation highlighting the scientific basis behind the technology, its relevance to current material being studied (light & EM radiation), its uses and potential improvements to it. • Describe the production of EM waves by accelerating charges.
2.0	**Students will be able to:** • Construct a list of technologies that rely in some way on the behavior of electromagnetic radiation (either as wave or particle). • Identify the parts of an electromagnetic wave in a diagram. • Describe how information can be transferred via electromagnetic waves. • Define/describe the following: *electromagnetic spectrum, interference, diffraction, electric field vector, magnetic field vector, total internal reflection, critical angle, fiber optics, Huygens Principle, dispersion, polarization, photon theory of light, photoelectric effect*
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 avaible via MyLab&Mastering). • Utilize peer tutors during class to work with struggling learners.
English Language Learners *(See http://www.state.nj.us/education/modelcurriculum/ela/ELLSupport.pdf)*	• 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).
Learners with an IEP	Each special education student has in Individualized Educational Plan (IEP) that details the specific accommodations, modifications, services, and support needed to level the playing field. This will enable that student to access the curriculum to the greatest extent possible in the least restrictive environment. These include: • Variation of time: adapting the time allotted for learning, task completion, or testing • Variation of input: adapting the way instruction is delivered • Variation of output: adapting how a student can respond to instruction • Variation of size: adapting the number of items the student is expected to complete • Modifying the content, process or product Additional resources are outlined to facilitate appropriate behavior and increase student engagement. The most frequently used modifications and accommodations can be viewed here. Teachers are encouraged to use the Understanding by Design Learning Guidelines (UDL). These guidelines offer a set of concrete suggestions that can be applied to any discipline to ensure that all learners can access and participate in learning opportunities. The framework can be viewed here www.udlguidelines.cast.org
Learners with a 504 • Refer to page four in the Parent and Educator Guide to Section 504 to assist in the development of appropriate plans.	

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) in order 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 as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- 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
Obtaining, Evaluating, and Communicating Information

Cross-Cutting Connections:
Interdependence of Sience, Engineering and Technology
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