Audubon Public School District

Physics

Curriculum Guide

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Course Description

Honors Physics with Lab

This course is for college-bound students, especially those intending to further their education in the math and science- related fields. It is specifically designed for those who are planning a career in engineering, engineering technology, electronics, computer science, physics, biology, chemistry, mathematics and other related fields. Topics studied include, but are not necessarily limited to, light, optics, the laws of motion, gravitation, electricity and magnetism and planetary motion. Laboratory work in this Physics course is built around the idea of "search and discovery" rather than the more traditional "cookbook" approach. It is, as a result, interesting and imaginative

Overview / Progressions

Grade 12: Physics

Overview		Earth and Space Science	Physical Science	Engineering, Technology, and Applications of Sciences
Unit 1	**Focus standards (Objectives)**		**HS-PS2-2** **HS-PS2-3**	**HS-ETS1-2** **HS-ETS1-3**
Unit 2	**Focus standards (Objectives)**	**HS-ESS1-4**	**HS-PS2-1** **HS-PS2-4**	
Unit 3	**Focus standards (Objectives)**		**HS-PS3-1** **HS-PS3-2** **HS-PS3-3**	
Unit 4	**Focus standards (Objectives)**		**HS-PS4-1** **HS-PS4-3** **HS-PS4-4** **HS-PS3-5**	**HS-ETS1-1** **HS-ETS1-4**

Physics	Grade 12	Unit 1	Marking Period 1

Physics Unit 1: Kinematics (30 Instructional Days)

To begin the year, students will be introduced to some new mathematics - vector mathematics. Drawing on previous algebraic and geometric principles, students will stretch their understanding of the world and its immutable physical laws. This begins with an understanding of direction as a component of measurement. The first unit will introduce this new math in a way that is easy to visualize - motion. Problem solving skills will be put to the test early on as students journey through the understanding of motion and its governing mathematics. The unit culminates with a design project to add in creativity and practice in group dynamics.

Overarching Essential Questions	Overarching Enduring Understandings
• What is a vector? • What is the difference between speed and velocity? • How can collisions be re-constructed to investigate what happened? • In what ways can a structure be altered to minimize or redirect forces?	• Vector quantities include a magnitude and a direction; scalar quantities include simply a magnitude • The change in certain measurements over time lead to more complex and informative measurements that can be used to describe an object's motion in great detail • An object's momentum is the product of its mass and its velocity • Total momentum of a system of objects is conserved when there is no net external force on the system.

Student Learning Objectives

What students should be able to do after instruction.	*Evidence Statements*
Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]	**HS-PS2-2**
Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.[Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it.	**HS-PS2-3**

Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]	
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**
Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	**HS-ETS1-3**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomena to describe explanations. (HS-PS2-2)	**PS2.A: Forces and Motion** ● Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) ● If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2) **ETS1.A: Defining and Delimiting Engineering Problems** ● Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given	**Cause and Effect** ● Systems can be designed to cause a desired effect. (HS-PS2-3) **Systems and System Models** ● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) -- ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** ● New technologies can have deep impacts on society and the environment, including some that were

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. ● Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3) ● Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) ● Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)	design meets them. (secondary to HS-PS23) **ETS1.C: Optimizing the Design Solution** ● Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (HS-ETS1-2), (secondary to (HS-PS2-3) **ETS1.B: Developing Possible Solutions** ● When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)	not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-3)

Embedded English Language Arts/Literacy and Mathematics
English Language Arts/Literacy -

WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-ETS1-3)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ETS1-3)
WHST.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.(HS-PS2-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-ETS1-3)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-ETS1-3)
Mathematics -	
MP.2	Reason abstractly and quantitatively. (HS-PS2-2),(HS-ETS1-3)
MP.4	Model with mathematics. (HS-PS2-2),(HS-ETS1-3)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-2)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-2)
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)

Prior Learning
Physical science- ● The greater the mass of the object, the greater the force needed to achieve the same change in motion. ● For any given object, a larger force causes a larger change in motion. ● All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. ● When two objects interact, each one exerts a force on the other that can cause momentum to be transferred from one object to the other. *Mathematics* ● Measured quantities can be combined algebraically to solve for a single, or in some cases, multiple unknowns. ● Graphs can be used to see the relationship between two or more variables. ● Mathematical expressions can be arranged to model certain physical phenomena.

Part A: Why do some measured quantities require a direction?	
Concepts	**Formative Assessment**
• Careful measurement is paramount to creating real world models for analysis and drawing proper conclusions. • An object's velocity is equal to its change in position over time; an object's acceleration is equal to its change in velocity over time.	*Students who understand the concepts are able to:* • Create mathematical models (algebraic and graphical) that can account for an object's position, velocity, acceleration, and momentum.

• All physical interactions are subject to certain laws.	• Analyze data using tools, technologies, and/or models to support the claim that momentum is conserved in all interactions.

Part B: Using what you know about impulse and the conservation of momentum in collisions, design, evaluate, and refine a car that keeps its passenger safe in a collision.	
Concepts	**Formative Assessment**
• 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. • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. • 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. • 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. • When evaluating solutions, it is important to take into account a range of constraints— including cost, safety, reliability, and aesthetics—and to consider social, cultural, and environmental impacts. • Systems can be designed to cause a desired effect.	*Students who understand the concepts are able to:* • 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. • Use mathematical representations of the quantitative conservation of momentum and the qualitative meaning of this principle in systems of two macroscopic bodies moving in one dimension. • Describe the boundaries and initial conditions of a system of two macroscopic bodies moving in one dimension. • Apply scientific and engineering ideas to design, evaluate, and refine a car that keeps its passenger safe in a collision. • Apply scientific ideas to solve a design problem for a car that keeps its passenger safe in a collision, taking into account possible unanticipated effects. • Use qualitative evaluations and/or algebraic manipulations to design and refine a car that keeps its passenger safe in a collision.

Leveraging English Language Arts/Literacy and Mathematics
English Language Arts/Literacy- • Conduct short as well as more sustained research projects to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. • Integrate and evaluate multiple sources of information presented in diverse formats and media in order to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. • Evaluate the hypotheses, data, analysis, and conclusions in a scientific or technical text in order to refine a device that minimizes the force on a macroscopic object during a collision. • Analyze multiple sources to inform design decisions. *Mathematics-* • Use symbols to represent the claim that the total momentum of a system of objects is conserved when there is no net force on the system and manipulate the representative symbols. Make sense of quantities and relationships between the total momentum of a system of objects and the net force on the system. • Use a mathematical model to describe how the total momentum of a system of objects is conserved when there is no net force on the system. Identify important quantities representing the total momentum of a system of objects and the net force on the system and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose. • Use units as a way to understand the conservation of the total momentum of a system of objects when there is no net force on the system. Choose and interpret units consistently in formulas representing the total momentum of a system of objects, and choose and interpret the scale and origin in graphs and data displays representing the conservation of the total momentum of a system of objects when there is no net force on the system. • Define appropriate quantities for the purpose of descriptive modeling of the conservation of the total momentum of a system of objects when there is no net force on the system. • Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the conservation of the total momentum of a system of objects and the net force on the system. • Create equations and inequalities in one variable and use them to determine that the total momentum of a system of objects is conserved when there is no net force on the system.

- Create equations in two or more variables to represent the relationship between conservation of the total momentum of a system of objects and the net force on the system.
- Rearrange formulas representing the conservation of momentum of a system of objects and the net force on the system to highlight a quantity of interest, using the same reasoning used in solving equations.
- Use symbols to represent the force on a macroscopic object during a collision and manipulate the representing symbols. Make sense of quantities and relationships between different device designs and the force on a macroscopic object during a collision.
- Use a mathematical model to describe how different device designs affect the force on a macroscopic object during a collision. Identify important quantities representing the force on a macroscopic object during a collision in different device designs to minimize force and map relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model (design) if it has not served its purpose.

Samples of Open Education Resources for this unit:

Parachute and Terminal Velocity:How does an object's speed change as it falls through the atmosphere? When first learning about how objects fall, usually just one force—gravity—is considered. Such a simplification only accurately describes falling motion in a vacuum. This model of a parachute carrying a load incorporates a second force—air resistance—and allows experimentation with two variables that affect its speed: the size of the parachute and the mass of its load. This model graphs both the parachute's height above the Earth's surface and its speed after it is released. Motion continues until a constant speed is achieved, the *terminal velocity*.

Differentiation & Real World Connections		
504	• preferential seating • extended time on tests and assignments • reduced homework or classwork • verbal, visual, or technology aids	• modified textbooks or audio-video materials • behavior management support • adjusted class schedules or grading • verbal testing

Enrichment	• Utilize collaborative media tools • Provide differentiated feedback • Opportunities for reflection • Opportunities for self-evaluation	• Encourage student voice and input • Model close reading • Distinguish long term and short term goals
IEP	• Utilize “skeleton notes” where some required information is already filled in for the student • Provide access to a variety of tools for responses • Provide opportunities to build familiarity and to practice with multiple media tools • Graphic organizers	• Leveled text and activities that adapt as students build skills • Provide multiple means of action and expression • Consider learning styles and interests • Provide differentiated mentors
ELLs	• Pre-teach new vocabulary and meaning of symbols • Embed glossaries or definitions • Provide translations • Connect new vocabulary to background knowledge	• Provide flash cards • Incorporate as many learning senses as possible • Portray structure, relationships, and associations through concept webs • Graphic organizers
At-risk	• Purposeful seating • Counselor involvement • Parent involvement	• Contracts • Alternate assessments • Hands-on learning

21st Century Skills	
• Creativity • Innovation	• Problem Solving • Communication

• Critical Thinking	• Collaboration
Integrating Technology	
• Chromebooks • Internet research • Online programs	• Virtual collaboration and projects • Presentations using presentation hardware and software
Career education	
• Weekly Discussions: The value of mastering multiple languages in the workforce.	• Equity Discussions: People who benefit from knowing multiple languages.

Physics	Grade 12	Unit 2	Marking Period 1/2

<table>
<tr><td colspan="2">Physics Unit 2: Newton’s Laws of Motion (55 Instructional Days)
In this unit, students will dive deep into Newton’s three laws of motion, and continue their exploration of vector math. Newton’s laws lay the groundwork to describe the motion of all objects, and have been utilized for great innovation through the years. Students will individually analyze the mathematics behind each of the three laws, and extend their knowledge by exploring their applications in various fields, through an engineering lens. Friction, and its implication on circular motion will be explored. This is to be extended into the mathematics of field forces, namely gravitational and electrostatic forces.</td></tr>
<tr><th>Overarching Essential Questions</th><th>Overarching Enduring Understandings</th></tr>
<tr><td>• What causes objects to move?
• How can a force be acting on an object if it’s not touching it?
• How can eclipses be predicted so far in advance?</td><td>• Newton’s three laws of motion can be used to accurately model the motion of macroscopic objects.
• Using Newton’s Law of Universal Gravitation and Kepler’s Laws, planetary motion can be accurately predicted.
• Forces can act through contact between two objects (friction, applied, tension) or indirectly in fields (gravitational, electric, magnetic).</td></tr>
<tr><th colspan="2">Student Learning Objectives</th></tr>
<tr><td>What students should be able to do after instruction.</td><td>Evidence Statements</td></tr>
<tr><td>Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]</td><td>HS-PS2-1</td></tr>
</table>

Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]	**HS-PS2-4**
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]	**HS-ESS1-4**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8	**PS2.A: Forces and Motion** ● Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) **PS2.B: Types of Interactions** ● Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) ● Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4)	**Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS21) **Patterns** ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) **Scale, Proportion, and Quantity** ● Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another

and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomena to describe explanations. (HS-PS2-4), (HS-ESS1-4)	**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. (HS-ESS1-4)	(e.g., linear growth vs. exponential growth). (HS-ESS1-4) -- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain NaturalPhenomena** ● Theories and laws provide explanations in science. (HS-PS2-1), (HS-PS2-4) ● Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1), (HS-PS2-4) -- ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** ● Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-4)

Embedded English Language Arts/Literacy and Mathematics	
English Language Arts/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)
Mathematics -	
MP.2	Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-4),(HS-ESS1-4)
MP.4	Model with mathematics. (HS-PS2-1),(HS-PS2-4),(HS-ESS1-4)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-4),(HS-ESS1-4)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1),(HS-PS2-4),(HS-ESS1-4)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-4),(HS-ESS1-4)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-4)
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1)

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),(HS-ESS1-4)
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1),(HS-ESS1-4)
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)

Prior Learning
Physical science- ● For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). ● The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. ● The greater the mass of the object, the greater the force needed to achieve the same change in motion. ● For any given object, a larger force causes a larger change in motion. ● All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. ● When two objects interact, each one exerts a force on the other that can cause energy to be transferred from one object to the other. ● Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

● Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. ● Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively).

Part A: Why does the speed limit decrease when a road is curved?	
Concepts	**Formative Assessment**
• Laws are statements or descriptions of the relationships among observable phenomena. • Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. • Newton's second law accurately predicts changes in the motion of macroscopic objects.	*Students who understand the concepts are able to:* • Analyze data using tools, technologies, and/or models 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. • Analyze data using one-dimensional motion at nonrelativistic speeds 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.

Part B: How can I be pushing so hard on an object that doesn't move?	
Concepts	**Formative Assessment**
● Newton's second law accurately predicts changes in the motion of macroscopic objects. ● Forces at a distance are explained by fields (gravitational, electric, magnetic) permeating space that can transfer energy through space. ● Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.	*Students who understand the concepts are able to:* • Use mathematical representations of phenomena to describe or explain how gravitational force is proportional to mass and inversely proportional to distance squared. • Use mathematical representations of phenomena to describe or explain how electrostatic force is proportional to charge and inversely proportional to distance squared.

	• Analyze data using two-dimensionalmotion at nonrelativistic speeds to supportthe claim that Newton's second law ofmotion describes the mathematicalrelationship among the net force on amacroscopic object, its mass, and itsacceleration.

Part C: It takes a long time to get to Pluto. How did NASA scientists know where Pluto would be when New Horizons got there?	
Concepts	**Formative Assessment**
• 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. • Newton's Law of Universal Gravitation provides the mathematical models to describe and predict the effects of gravitational forces between distant objects. • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.	*Students who understand the concepts are able to:* • Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. • Use mathematical and computational representations of Newtonian gravitational laws governing orbital motion that apply to moons and human-made satellites. • Use algebraic thinking to examine scientific data and predict the motion of orbiting objects in the solar system. • Demonstrate how Newton's Law of Universal Gravitation provides explanations for observed scientific phenomena.

Leveraging English Language Arts/Literacy and Mathematics
English Language Arts/Literacy- • Cite specific textual evidence 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. • Integrate and evaluate multiple sources of information presented in diverse formats and media in order 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.

- Draw evidence from informational texts 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.

Mathematics-

- Represent 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 symbolically and manipulate the representative symbols. Make sense of quantities and relationships among net force on a macroscopic object, its mass, and its acceleration.
- Use a mathematical model to describe how Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. Identify important quantities representing the net force on a macroscopic object, its mass, and its acceleration and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. Choose and interpret units consistently in Newton's second law of motion, and choose and interpret the scale and origin in graphs and data displays representing the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- Define appropriate quantities for the purpose of descriptive modeling of Newton's second law of motion.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the net force on a macroscopic object, its mass, and its acceleration.
- Interpret expressions that represent the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration in terms of its context.
- Choose and produce an equivalent form of Newton's second law to reveal and explain properties of the quantity represented by the expression.
- Create equations and inequalities in one variable and use them to solve for the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- Create equations in two or more variables to represent relationships among the net force on a macroscopic object, its mass, and its acceleration; graph equations on coordinate axes with labels and scales.
- Rearrange Newton's second law to highlight a quantity of interest, using the same reasoning used in solving equations.
- Graph the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

• Represent data of the net force on a macroscopic object, its mass, and its acceleration with plots on the real number line (dot plots, histograms, and box plots).

Samples of Open Education Resources for this unit:
Forces in One Dimension: Explore the forces at work when you try to push a filing cabinet. Create an applied force and see the resulting friction force and total force acting on the cabinet. Charts show the forces, position, velocity, and acceleration vs. time. View a Free Body Diagram of all the forces (including gravitational and normal forces). Forces and Motion: Explore the forces at work when you try to push a filing cabinet. Create an applied force and see the resulting friction force and total force acting on the cabinet. Charts show the forces, position, velocity, and acceleration vs. time. View a Free Body Diagram of all the forces (including gravitational and normal forces). Gravity Force Lab:Visualize the gravitational force that two objects exert on each other. Adjust properties of the objects to see how changing the properties affect the gravitational attraction. Electrostatics: Use a series of interactive models and games to explore electrostatics. Learn about the effects positive and negative charges have on one another, and investigate these effects further through games. Learn about Coulomb's law and the concept that both the distance between the charges and the difference in the charges affect the strength of the force. Explore polarization at an atomic level, and learn how a material that does not hold any net charge can be attracted to a charged object.

Differentiation & Real World Connections		
504	● preferential seating ● extended time on tests and assignments ● reduced homework or classwork ● verbal, visual, or technology aids	● modified textbooks or audio-video materials ● behavior management support ● adjusted class schedules or grading ● verbal testing

<table>
<tr><td>Enrichment</td><td>Utilize collaborative media tools
Provide differentiated feedback
Opportunities for reflection
Opportunities for self-evaluation</td><td>Encourage student voice and input
Model close reading
Distinguish long term and short term goals</td></tr>
<tr><td>IEP</td><td>Utilize “skeleton notes” where some required information is already filled in for the student
Provide access to a variety of tools for responses
Provide opportunities to build familiarity and to practice with multiple media tools
Graphic organizers</td><td>Leveled text and activities that adapt as students build skills
Provide multiple means of action and expression
Consider learning styles and interests
Provide differentiated mentors</td></tr>
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<tr><td>Chromebooks
Internet research
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<tr><td>Weekly Discussions: The value of mastering multiple languages in the workforce.</td><td>Equity Discussions: People who benefit from knowing multiple languages.</td></tr>
</table>

Physics	Grade 12	Unit 3	Marking Period 3

Physics Unit 3: Mechanical Energy (40 Instructional Days) In this unit, students will begin their study of the physics of energy with a look at mechanical energy. Each type of mechanical energy (kinetic, gravitational potential, elastic potential) will be modeled individually, and a unifying equation will be used to balance the energy of complex systems. The unit will culminate with a Rube Goldberg machine built from scratch, with students accounting for energy balance and loss.	
Overarching Essential Questions	**Overarching Enduring Understandings**
• How does energy manifest itself on the macroscopic scale? • How is it possible to move something but do absolutely no work? • What are some reasons for loss of efficiency found when combining simple machines?	• The total energy of a closed, isolated system is constant. Within the system, the energy can change form, but the total amount of energy doesn't change. • Work is the transfer of energy by means of forces. The work done on the system is equal to the change in energy of the system. • Machines, whether powered by engines or humans, do not change work, but make it easier.

Student Learning Objectives	
What students should be able to do after instruction.	*Evidence Statements*
Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]	**HS-PS3-1**
Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).[Clarification Statement: Examples of phenomena at the macroscopic scale could include the	**HS-PS3-2**

conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]	
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.[Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]	**HS-PS3-3**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8	**PS3.A: Definitions of Energy** ● Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-2) ● At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2)	**Systems and System Models** ● Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-1) **Energy and Matter** ● Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3) ● Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2)

and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)	● These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2) **PS3.B: Conservation of Energy and Energy Transfer** ● Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) ● Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1) ● Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged 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	- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ● Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

	predict and describe system behavior. (HS-PS3-1) ● The availability of energy limits what can occur in any system. (HS-PS3-1)	

Embedded English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

SL.11-12.5 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-PS3-1),(HS-PS3-2)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a selfgenerated 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)

Mathematics-

MP.2 Reason abstractly and quantitatively. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3)

MP.4 Model with mathematics. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3)

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1),(HS-PS3-3)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-3)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1),(HS-PS3-3)

Prior Learning

Physical science-

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on the objects' relative positions.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively).
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Part A: What goes on in a spring that makes it able to move other objects?

Concepts	Formative Assessment
• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles).	*Students who understand the concepts are able to:* • Develop and use models based on evidence to illustrate that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems.

• Energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. • The availability of energy limits what can occur in any system.	• Use mathematical expressions to quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compressions of a spring) and how kinetic energy depends on mass and speed. • Use mathematical expressions and the concept of conservation of energy to predict and describe system behavior.

Part B: Complete a given task (different year-to-year) using a Rube Goldberg Machine.	
Concepts	**Formative Assessment**
• 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. The change in energy of a system is also equal to the work done either by or on the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • The availability of energy limits what can occur in any system. • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximation inherent in models. • Science assumes that the universe is a vast single system in which basic laws are consistent.	*Students who understand the concepts are able to:* • Use basic algebraic expressions or computations to create a computational model to calculate the change in the energy of one component in a system (limited to two or three components) when the change in energy of the other component(s) and energy flows in and out of the system are known. • Explain the meaning of mathematical expressions used to model the change in the energy of one component in a system (limited to two or three components) when the change in energy of the other component(s) and out of the system are known. • Use mathematical expressions and the concept of conservation of energy to predict and describe system behavior.

Leveraging English Language Arts/Literacy and Mathematics
English Language Art/Literacy- • Make strategic use of digital media in presentations to enhance understanding of the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.

- Make strategic use of digital media in presentations to support the claim that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).
- Conduct short as well as more sustained research projects to describe energy conversions as energy flows into, out of, and within systems.
- Integrate and evaluate multiple sources of information presented in diverse formats and media to describe energy conversions as energy flows into, out of, and within systems.
- Evaluate scientific text regarding energy conversions to determine the validity of the claim that although energy cannot be destroyed, it can be converted into less useful forms.
- Compare different sources of information describing energy conversions to create a coherent understanding of energy flows into, out of, within, and between systems.

Mathematics-

- Represent symbolically an explanation about the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known, and manipulate the representing symbols. Make sense of quantities and relationships about 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 symbolically, and manipulate the representing symbols.
- Use a mathematical model to explain the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known. Identify important quantities in energy of components in systems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known; choose and interpret units consistently in formulas representing how the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known; choose and interpret the scale and the origin in graphs and data displays representing that the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.

- Define appropriate quantities for the purpose of descriptive modeling of how the quantitative change in energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing how the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Represent symbolically that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and manipulate the representing symbols. Make sense of quantities and relationships between the energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).
- Represent the conversion of one form of energy into another symbolically, considering criteria and constraints, and manipulate the representing symbols. Make sense of quantities and relationships in the conversion of one form of energy into another.
- Use a mathematical model of how energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects). Identify important quantities representing how the energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use a mathematical model to describe the conversion of one form of energy into another and to predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the conversion of one form of energy into another and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the conversion of one form of energy into another; choose and interpret units consistently in formulas representing energy conversions as energy flows into, out of, and within systems; choose and interpret the scale and the origin in graphs and data displays representing energy conversions as energy flows into, out of, and within systems.
- Define appropriate quantities for the purpose of descriptive modeling of a device to convert one form of energy into another form of energy.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of energy conversions as energy flows into, out of, and within systems.

Samples of Open Education Resources for this unit:
Energy Skate Park: Basics:Learn about conservation of energy with a skater gal! Explore different tracks and view the kinetic energy, potential energy and friction as she moves. Build your own tracks, ramps, and jumps for the skater.

Differentiation & Real World Connections		
504	• preferential seating • extended time on tests and assignments • reduced homework or classwork • verbal, visual, or technology aids	• modified textbooks or audio-video materials • behavior management support • adjusted class schedules or grading • verbal testing
Enrichment	• Utilize collaborative media tools • Provide differentiated feedback • Opportunities for reflection • Opportunities for self-evaluation	• Encourage student voice and input • Model close reading • Distinguish long term and short term goals
IEP	• Utilize “skeleton notes” where some required information is already filled in for the student • Provide access to a variety of tools for responses • Provide opportunities to build familiarity and to practice with multiple media tools • Graphic organizers	• Leveled text and activities that adapt as students build skills • Provide multiple means of action and expression • Consider learning styles and interests • Provide differentiated mentors

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Embed glossaries or definitions
Provide translations
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Physics	Grade 12	Unit 4	Marking Period 3/4

<table>
<tr><td colspan="2">Physics Unit 4: Wave and Particle Energy (45 Instructional Days)
This unit will see students continue their exploration of energy, though the focus will shift to the micro- and nano-scopic. The wave-particle duality of nature will be explored through the modeling of light, sound, and electrical energy, and their relationship to one another. Students will use geometric principles to locate reflected and refracted images, look at the propagation of longitudinal sound waves, and diagram and model dc circuits.</td></tr>
<tr><td>Overarching Essential Questions</td><td>Overarching Enduring Understandings</td></tr>
<tr><td>● How can light be both a wave and a particle at the same time?
● How does light behave at the boundary between two mediums?
● Where, exactly, is the ‘man in the mirror’?
● How do sound and light waves compare?
● Why is it ironic that Tesla is largely a company focused on battery-powered objects?</td><td>● Light is a form of electromagnetic radiation with a wavelength between 400 and 700 nm. It can act as both a wave and a particle, both of which explain certain phenomena associated with light.
● Properties of light include reflection, refraction, diffusion, and interference. Lenses and mirrors are used to harness these properties
● Longitudinal and transverse waves have properties that are similar but energy that is transferred in these two ways can differ greatly.
● Certain types of materials have atomic properties such that electrons can be coaxed to move through the material and transfer energy. This form of energy is known as electrical energy.
● The flow of electric energy is called current. There are two types of current – alternating current and direct current – in wide use today.</td></tr>
<tr><td colspan="2">Student Learning Objectives</td></tr>
<tr><td>What students should be able to do after instruction.</td><td>Evidence Statements</td></tr>
</table>

Use mathematical representations to support a claim regarding relationships among the frequency, wavelength,and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]	**HS-PS4-1**
Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [*Assessment Boundary:* Assessment does not include using quantum theory.]	**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.[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]	**HS-PS4-4**
Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]	**HS-PS3-5**
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**
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**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**

Engaging in Argument from Evidence

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.(HS-PS4-3)

Developing and Using Models

- Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-5)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-PS4-4, HS-PS4-5)

- Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or

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)
- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3)

PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-PS4-3)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4), (HS-PS3-5)

Connections to Engineering, Technology, and Applications of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science

media reports, verifying the data when possible. (HS-PS4-4) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)	rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4) **PS3.C: Relationship Between Energy and Forces** • When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5)	community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)

Embedded English Language Arts/Literacy and Mathematics	
English Language Arts/Literacy -	
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-3), (HS-PS4-4)
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-PS4-3), (HS-PS4-4)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1), (HS-PS4-4)

RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4), (HS-PS3-5)

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-PS4-1), (HS-PS4-3), (HS-PS3-5)
MP.4	Model with mathematics. (HS-PS4-1), (HS-PS3-5)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1), (HS-PS4-3)
HSA-SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1), (HS-PS4-3)
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1), (HS-PS4-3)

Prior Learning

Physical science-

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.
- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.
- Atoms have two distinct parts: the nucleus, which contains protons and neutrons, and the electron cloud, which contains electrons.
- Electrons are negatively charged and are electrostatically attracted to protons, which are positively charged.
- Different atoms have different numbers of protons and electrons. The arrangement of electrons dictates certain properties of that atom.
- Energy can be converted to different forms (e.g., kinetic, chemical, thermal) and, in doing so, is conserved.

Mathematics-

- Mathematical expressions can be arranged to model certain physical phenomena.
- Mathematical expressions can be rearranged to isolate a certain variable.

Part A: How does an automatic door know when to open?

Concepts	Formative Assessment
• 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. • 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.	*Students who understand the concepts are able to:* • 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. • Use models (e.g., physical,mathematical,computer models) to simulate electromagnetic radiation systems and interactions—including energy, matter,and information flows—within and between systems at different scales.

Part B: Why *are* objects closer than they appear?

Concepts	Formative Assessment
• Light, and other forms of electromagnetic radiation, can be absorbed or reflected. There are certain laws governing the reflection of light off of both flat and curved surfaces. • By changing the shape of the surface doing the reflecting, a reflected light ray can be moved around with precision.	*Students who understand the concepts are able to:* • Give qualitative and quantitative descriptions of how light responds when reflecting off of different surfaces. • Use algebraic relationships to quantitatively describe relationships among incident and reflected light rays. • Use models (e.g., physical,mathematical,computer models) to simulate the path a light wave takes into and off of a mirror.

• Absorbed light can and will travel different speeds depending on the optical density of the substance. This lays the foundation for the use of lenses to see extremely small and distant objects.	• Calculate the image size, location, and orientation using the lensmaker's formula

Part C: How is electricity like plumbing?	
Concepts	**Formative Assessment**
• Electrons travel to move electrical energy. Properties of the material that carries the current can have a drastic effect on the quality and safety of the circuit. • Voltage, resistance, and current are related by Ohm's Law: V = I * R. • Power is calculated using the Power Law: P = I * V. • Resistors can be arranged in series or parallel. Different arrangements of resistors will produce circuits with different properties. • Kirchoff's laws can be used to analyze multiple-resistor circuits. • Resistors are labeled according to a system of colored bands which display their resistance in ohms. • Multiple resistors can be combined to act as a single resistor. • Electrical energy can be utilized to do work by being converted into some other form (e.g., thermal, mechanical)	*Students who understand the concepts are able to:* • Evaluate different materials to determine if they would be ideal in electronic circuitry. Cost, material properties, commercial application, and commercial availability are factors to be analyzed. • Use computer models to design and build a circuit given certain constraints on resistance, voltage, current, power, or some combination of those. • Design and build a circuit that is powered by an Arduino sketch. Test the sketch using the circuit. Calculations should justify the need for certain resistors. Resistors should be identified by their color bands. • Use comments to annotate a sketch and optimize a sketch by using the most efficient code possible. Sketches should be double checked to ensure efficiency.

Part D: Are personal batteries the answer to our energy problems?	
Concepts	**Formative Assessment**
• Batteries can be used to store energy for later use. By collecting energy in sustainable ways and storing it in batteries, fossil fuel consumption could be reduced. • Continuous power generation is messy but allows for the extremely large capacity of demand globally. • Alternating current and direct current both have benefits and drawbacks alike. A hybrid system is the best solution for highly functioning and reliable large-scale energy infrastructure.	*Students who understand the concepts are able to:* • Evaluate the different types of electrical delivery and storage (alternating and direct current) to propose a long-term energy solution. • Use multiple lines of evidence to support an argument for or against a certain type of current. • Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) comparing alternating current and direct current.

Leveraging English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

- Cite textual evidence to support analysis of science and technical texts describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., qualitative data, video multimedia) in order to address the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Gather relevant information from multiple authoritative print and digital sources describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, using advanced searches effectively; assess the strengths and limitations of

each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

- Assess the extent to which the reasoning and evidence in a text support the advantages of storing and moving electricity using alternating current or direct current.
- Cite specific textual evidence to support the advantages of using digital transmission and storage of information, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Conduct short as well as more sustained research projects to describe energy conversions as energy flows into, out of, and within systems.
- Integrate and evaluate multiple sources of information presented in diverse formats and media to describe energy conversions as energy flows into, out of, and within systems.
- Evaluate scientific text regarding energy conversions to determine the validity of the claim that although energy cannot be destroyed, it can be converted into less useful forms.
- Compare different sources of information describing energy conversions to create a coherent understanding of energy flows into, out of, within, and between systems.

Mathematics-

- Represent symbolically that electromagnetic radiation can be described either by a wave model or aparticle model and that for some situations one model is more useful than the other, and manipulate the representing symbols.
- Make sense of quantities and relationships between the wave model and the particle model of electromagnetic radiation.
- Interpret expressions that represent the wave model and particle model of electromagnetic radiation in terms of the usefulness of the model depending on the situation.
- Choose and produce an equivalent form of an expression to reveal and explain properties of electromagnetic radiation.
- Rearrange formulas representing electromagnetic radiation to highlight a quantity of interest, using the same reasoning as in solving equations.
- Define appropriate quantities for the purpose of descriptive modeling of how the quantitative change in energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Represent symbolically that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and manipulate the representing symbols.

Make sense of quantities and relationships between the energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).

- Represent the conversion of one form of energy into another symbolically, considering criteria and constraints, and manipulate the representing symbols. Make sense of quantities and relationships in the conversion of one form of energy into another.
- Use a mathematical model of how energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects). Identify important quantities representing how the energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use a mathematical model to describe the conversion of one form of energy into another and to predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the conversion of one form of energy into another and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Samples of Open Education Resources for this unit:
Introduction to the Electromagnetic Spectrum: NASA background resource
Radio Waves and Electromagnetic Fields: PHeT simulation demonstrating wave generation, propagation and detection with antennas.
Wave Interference: PHeT simulation of both mechanical and optical wave phenomena
Photoelectric Effect PHeT: PHeT simulation addressing evidence for particle nature of electromagnetic radiation
Interaction of Molecules with Electromagnetic Radiation: PHeT simulation exploring the effect of microwave, infrared, visible and ultraviolet radiation on various molecules.
Wave/Particle Dualism: PHeT simulation of wave and particle views of interference phenomena.
X-ray Technology: OSP Simulation of optimization of X-ray contrast by varying energy of X-rays, materials characteristics and measurement parameters
Wave on a string: Students will watch a wave on a string. Adjusting the amplitude, frequency, damping and tension will demonstrate wave properties.

Refraction through Glass:Students will trace the course of different rays of light through a rectangular glass slab at different angles of incidence, measure the angle of incidence, refraction, measure the lateral displacement to verify Snell`s law. PhET Circuit Construction Kit (DC only): is online simulation software to model DC circuits. PhET Circuit Construction Kit (AC and DC): is online simulation software to model AC and DC circuits. PhET Simulation – Ohm's Law: is online simulation software to model the relationship described by Ohm's Law. PhET Simulation – Resistance in a Wire: is online simulation software to model the relationship to calculate a wire's resistance. Edison v. Westinghouse: is an article on The Smithsonian that tells of the "Battle of Currents" between Thomas Edison and George Westinghouse/Nikola Tesla.

Differentiation & Real World Connections		
504	• preferential seating • extended time on tests and assignments • reduced homework or classwork • verbal, visual, or technology aids	• modified textbooks or audio-video materials • behavior management support • adjusted class schedules or grading • verbal testing
Enrichment	• Utilize collaborative media tools • Provide differentiated feedback • Opportunities for reflection • Opportunities for self-evaluation	• Encourage student voice and input • Model close reading • Distinguish long term and short term goals
IEP	• Utilize "skeleton notes" where some required information is already filled in for the student • Provide access to a variety of tools for responses • Provide opportunities to build familiarity and to practice with multiple media tools • Graphic organizers	• Leveled text and activities that adapt as students build skills • Provide multiple means of action and expression • Consider learning styles and interests • Provide differentiated mentors

<table>
<tr><td>ELLs</td><td>Pre-teach new vocabulary and meaning of symbols
Embed glossaries or definitions
Provide translations
Connect new vocabulary to background knowledge</td><td>Provide flash cards
Incorporate as many learning senses as possible
Portray structure, relationships, and associations through concept webs
Graphic organizers</td></tr>
<tr><td>At-risk</td><td>Purposeful seating
Counselor involvement
Parent involvement</td><td>Contracts
Alternate assessments
Hands-on learning</td></tr>
<tr><td colspan="3">21st Century Skills</td></tr>
<tr><td colspan="2">Creativity
Innovation
Critical Thinking</td><td>Problem Solving
Communication
Collaboration</td></tr>
<tr><td colspan="3">Integrating Technology</td></tr>
<tr><td colspan="2">Chromebooks
Internet research
Online programs</td><td>Virtual collaboration and projects
Presentations using presentation hardware and software</td></tr>
<tr><td colspan="3">Career education</td></tr>
<tr><td colspan="2">Weekly Discussions: The value of mastering multiple languages in the workforce.</td><td>Equity Discussions: People who benefit from knowing multiple languages.</td></tr>
</table>

Appendix

PHYSICS Unit 1: Newton's Laws of Motion (75 Instructional Days)	
Overarching Essential Questions	**Overarching Enduring Understandings**
• What causes objects to move? • How can a force be acting on an object if it's not touching it? • How can eclipses be predicted so far in advance? • In what ways can a structure be altered to minimize or redirect forces?	• Newton's three laws of motion can be used to accurately model the motion of macroscopic objects. • Using Newton's Law of Universal Gravitation and Kepler's Laws, planetary motion can be accurately predicted. • Forces can act through contact between two objects (friction, applied, tension) or indirectly in fields (gravitational, electric, magnetic). • Total momentum of a system of objects is conserved when there is no net external force on the system.

Student Learning Objectives	
What students should be able to do after instruction.	*Evidence Statements*
Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]	**HS-PS2-1**
Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]	**HS-PS2-2**

Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.[Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]	**HS-PS2-3**
Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]	**HS-PS2-4**
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]	**HS-ESS1-4**
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**
Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	**HS-ETS1-3**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)	**PS2.A: Forces and Motion** ● Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) ● Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) ● If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes	**Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS21) ● Systems can be designed to cause a desired effect. (HS-PS2-3) **Systems and System Models**

Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomena to describe explanations. (HS-PS2-2), (HS-PS2-4), (HS-ESS1-4) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. ● Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3) ● Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) ● Evaluate a solution to a complex real-world problem, based on scientific knowledge,	in the momentum of objects outside the system. (HS-PS2-2) **PS2.B: Types of Interactions** ● Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) ● Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4) **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. (HS-ESS1-4) **ETS1.A: Defining and Delimiting Engineering Problems** ● Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS23) **ETS1.C: Optimizing the Design Solution** ● Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over	● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) **Patterns** ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) **Scale, Proportion, and Quantity** ● Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4) --- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain NaturalPhenomena** ● Theories and laws provide explanations in science. (HS-PS2-1), (HS-PS2-4) ● Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1), (HS-PS2-4) --- ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** ● Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may

student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)	others (tradeoffs) may be needed. (HS-ETS1-2), (secondary to (HS-PS2-3) **ETS1.B: Developing Possible Solutions** ● When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)	involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-4) ● New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-3)

Embedded English Language Arts/Literacy and Mathematics
English Language Arts/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.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-ETS1-3)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ETS1-3)
WHST.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.(HS-PS2-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-ETS1-3)

WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-ETS1-3)
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1)
Mathematics -	
MP.2	Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4),(HS-ETS1-3)
MP.4	Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4),(HS-ETS1-2),(HS-ETS1-3)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-ESS1-4)
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-4)
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1)
HSA.CED.A.1	Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)
HSA.CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1),(HS-PS2-2),(HS-ESS1-4)
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1),(HS-PS2-2),(HS-ESS1-4)
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)

Three-Dimensional Teaching and Learning

Prior Learning
Physical science- ● For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s third law). ● The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. ● The greater the mass of the object, the greater the force needed to achieve the same change in motion. ● For any given object, a larger force causes a larger change in motion. ● All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. ● When two objects interact, each one exerts a force on the other that can cause energy to be transferred from one object to the other. ● Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. ● Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. ● Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively).

Part A: Why does the speed limit decrease when a road is curved?	
Concepts	**Formative Assessment**
• Laws are statements or descriptions of the relationships among observable phenomena. • Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. • Newton’s second law accurately predicts changes in the motion of macroscopic objects.	*Students who understand the concepts are able to:* • Analyze data using tools, technologies, and/or models 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. • Analyze data using one-dimensionalmotion at nonrelativistic speeds to supportthe claim that Newton's second law ofmotion describes the

	mathematicalrelationship among the net force on amacroscopic object, its mass, and itsacceleration.

Part B: How can I be pushing so hard on an object that doesn’t move?	
Concepts	**Formative Assessment**
● Newton’s second law accurately predicts changes in the motion of macroscopic objects. ● Forces at a distance are explained by fields (gravitational, electric, magnetic) permeating space that can transfer energy through space. ● Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.	*Students who understand the concepts are able to:* • Use mathematical representations of phenomena to describe or explain how gravitational force is proportional to mass and inversely proportional to distance squared. • Use mathematical representations of phenomena to describe or explain how electrostatic force is proportional to charge and inversely proportional to distance squared. • Analyze data using two-dimensionalmotion at nonrelativistic speeds to supportthe claim that Newton's second law ofmotion describes the mathematicalrelationship among the net force on amacroscopic object, its mass, and itsacceleration.

Part C: It takes a long time to get to Pluto. How did NASA scientists know where Pluto would be when New Horizons got there?	
Concepts	**Formative Assessment**
• 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. • Newton’s Law of Universal Gravitation provides the mathematical models to describe and predict the effects of gravitational forces between distant objects. • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.	*Students who understand the concepts are able to:* • Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. • Use mathematical and computational representations of Newtonian gravitational laws governing orbital motion that apply to moons and human-made satellites. • Use algebraic thinking to examine scientific data and predict the motion of orbiting objects in the solar system. • Demonstrate how Newton’s Law of Universal Gravitation provides explanations for observed scientific phenomena.

Part D: Using what you know about impulse and the conservation of momentum in collisions, design, evaluate, and refine a car that keeps its passenger safe in a collision.	
Concepts	**Formative Assessment**
• 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. • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. • 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. • 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. • When evaluating solutions, it is important to take into account a range of constraints— including cost, safety, reliability, and aesthetics—and to consider social, cultural, and environmental impacts. • Systems can be designed to cause a desired effect.	*Students who understand the concepts are able to:* • 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. • Use mathematical representations of the quantitative conservation of momentum and the qualitative meaning of this principle in systems of two macroscopic bodies moving in one dimension. • Describe the boundaries and initial conditions of a system of two macroscopic bodies moving in one dimension. • Apply scientific and engineering ideas to design, evaluate, and refine a car that keeps its passenger safe in a collision. • Apply scientific ideas to solve a design problem for a car that keeps its passenger safe in a collision, taking into account possible unanticipated effects. • Use qualitative evaluations and/or algebraic manipulations to design and refine a car that keeps its passenger safe in a collision.

Modifications: *Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.(See NGSS Appendix D)*

- *Restructure lesson using UDL principles (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)*
- *Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.*
- *Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).*
- *Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).*

- *Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).*
- *Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.*
- *Use project-based science learning to connect science with observable phenomena.*
- *Structure the learning around explaining or solving a social or community-based issue.*
- *Provide ELL students with multiple literacy strategies.*
- *Collaborate with after-school programs or clubs to extend learning opportunities.*

Leveraging English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

- Cite specific textual evidence 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.
- Integrate and evaluate multiple sources of information presented in diverse formats and media in order 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.
- Draw evidence from informational texts 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.
- Conduct short as well as more sustained research projects to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
- Integrate and evaluate multiple sources of information presented in diverse formats and media in order to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
- Evaluate the hypotheses, data, analysis, and conclusions in a scientific or technical text in order to refine a device that minimizes the force on a macroscopic object during a collision.
- Analyze multiple sources to inform design decisions.

Mathematics-

- Represent 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 symbolically and manipulate the representative symbols. Make sense of quantities and relationships among net force on a macroscopic object, its mass, and its acceleration.

- Use a mathematical model to describe how Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. Identify important quantities representing the net force on a macroscopic object, its mass, and its acceleration and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. Choose and interpret units consistently in Newton's second law of motion, and choose and interpret the scale and origin in graphs and data displays representing the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- Define appropriate quantities for the purpose of descriptive modeling of Newton's second law of motion.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the net force on a macroscopic object, its mass, and its acceleration.
- Interpret expressions that represent the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration in terms of its context.
- Choose and produce an equivalent form of Newton's second law to reveal and explain properties of the quantity represented by the expression.
- Create equations and inequalities in one variable and use them to solve for the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- Create equations in two or more variables to represent relationships among the net force on a macroscopic object, its mass, and its acceleration; graph equations on coordinate axes with labels and scales.
- Rearrange Newton's second law to highlight a quantity of interest, using the same reasoning used in solving equations.
- Graph the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- Represent data of the net force on a macroscopic object, its mass, and its acceleration with plots on the real number line (dot plots, histograms, and box plots).
- Use symbols to represent the claim that the total momentum of a system of objects is conserved when there is no net force on the system and manipulate the representative symbols. Make sense of quantities and relationships between the total momentum of a system of objects and the net force on the system.
- Use a mathematical model to describe how the total momentum of a system of objects is conserved when there is no net force on the system. Identify important quantities representing the total momentum of a system of objects and the net force on the system and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the conservation of the total momentum of a system of objects when there is no net force on the system. Choose and interpret units consistently in formulas representing the total momentum of a system of objects, and choose and interpret the scale and origin in graphs and data displays representing the conservation of the total momentum of a system of objects when there is no net force on the system.

- Define appropriate quantities for the purpose of descriptive modeling of the conservation of the total momentum of a system of objects when there is no net force on the system.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the conservation of the total momentum of a system of objects and the net force on the system.
- Create equations and inequalities in one variable and use them to determine that the total momentum of a system of objects is conserved when there is no net force on the system.
- Create equations in two or more variables to represent the relationship between conservation of the total momentum of a system of objects and the net force on the system.
- Rearrange formulas representing the conservation of momentum of a system of objects and the net force on the system to highlight a quantity of interest, using the same reasoning used in solving equations.
- Use symbols to represent the force on a macroscopic object during a collision and manipulate the representing symbols. Make sense of quantities and relationships between different device designs and the force on a macroscopic object during a collision.
- Use a mathematical model to describe how different device designs affect the force on a macroscopic object during a collision. Identify important quantities representing the force on a macroscopic object during a collision in different device designs to minimize force and map relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model (design) if it has not served its purpose.

Samples of Open Education Resources for this unit:

Forces in One Dimension: Explore the forces at work when you try to push a filing cabinet. Create an applied force and see the resulting friction force and total force acting on the cabinet. Charts show the forces, position, velocity, and acceleration vs. time. View a Free Body Diagram of all the forces (including gravitational and normal forces).

Forces and Motion: Explore the forces at work when you try to push a filing cabinet. Create an applied force and see the resulting friction force and total force acting on the cabinet. Charts show the forces, position, velocity, and acceleration vs. time. View a Free Body Diagram of all the forces (including gravitational and normal forces).

Parachute and Terminal Velocity:How does an object's speed change as it falls through the atmosphere? When first learning about how objects fall, usually just one force—gravity—is considered. Such a simplification only accurately describes falling motion in a vacuum. This model of a parachute carrying a load incorporates a second force—air resistance—and allows experimentation with two variables that affect its speed: the size of the parachute and the mass of its load. This model graphs both the parachute's height above the Earth's surface and its speed after it is released. Motion continues until a constant speed is achieved, the *terminal velocity*.

Gravity Force Lab:Visualize the gravitational force that two objects exert on each other. Adjust properties of the objects to see how changing the properties affect the gravitational attraction.

Electrostatics: Use a series of interactive models and games to explore electrostatics. Learn about the effects positive and negative charges have on one another, and investigate these effects further through games. Learn about Coulomb's law and the concept that both the distance between the charges and the difference in the charges affect the strength of the force. Explore polarization at an atomic level, and learn how a material that does not hold any net charge can be attracted to a charged object.

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PHYSICS Unit 2: Energy and Work(45 Instructional Days)	
Overarching Essential Questions	**Overarching Enduring Understandings**
● How does energy manifest itself on the macroscopic scale? ● How is it possible to move something but do absolutely no work? ● What are some reasons for loss of efficiency found when combining simple machines?	● The total energy of a closed, isolated system is constant. Within the system, the energy can change form, but the total amount of energy doesn't change. ● Work is the transfer of energy by means of forces. The work done on the system is equal to the change in energy of the system. ● Machines, whether powered by engines or humans, do not change work, but make it easier.
Student Learning Objectives	
What students should be able to do after instruction.	*Evidence Statements*
Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]	**HS-PS3-1**
Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an	**HS-PS3-2**

object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]	

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)	**PS3.A: Definitions of Energy** ● Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-2) ● At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) ● These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2) **PS3.B: Conservation of Energy and Energy Transfer** ● Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)	**Systems and System Models** ● Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-1) **Energy and Matter** ● Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2) - ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ● Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

	- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1) - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) - The availability of energy limits what can occur in any system. (HS-PS3-1)	

Embedded English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

SL.11-12.5	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-PS3-1),(HS-PS3-2)

Mathematics-

MP.2	Reason abstractly and quantitatively. (HS-ETS1-1),(HS-ETS1-3)
MP.4	Model with mathematics. (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-3)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-2)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1),(HS-PS3-2)

Three-Dimensional Teaching and Learning

Prior Learning
Physical science- • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. • A system of objects may also contain stored (potential) energy, depending on the objects' relative positions. • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. • When the motion energy of an object changes, there is inevitably some other change in energy at the same time. • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. • Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively). • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Energy is spontaneously transferred out of hotter regions or objects and into colder ones. • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Part A: What goes on in a spring that makes it able to move other objects?	
Concepts	**Formative Assessment**
• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.	*Students who understand the concepts are able to:*

• In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). • Energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. • The availability of energy limits what can occur in any system.	• Develop and use models based on evidence to illustrate that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. • Use mathematical expressions to quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compressions of a spring) and how kinetic energy depends on mass and speed. • Use mathematical expressions and the concept of conservation of energy to predict and describe system behavior.

Part B: Complete a given task (different year-to-year) using a Rube Goldberg Machine.	
Concepts	**Formative Assessment**
• 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. The change in energy of a system is also equal to the work done either by or on the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • The availability of energy limits what can occur in any system. • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximation inherent in models. • Science assumes that the universe is a vast single system in which basic laws are consistent.	*Students who understand the concepts are able to:* • Use basic algebraic expressions or computations to create a computational model to calculate the change in the energy of one component in a system (limited to two or three components) when the change in energy of the other component(s) and energy flows in and out of the system are known. • Explain the meaning of mathematical expressions used to model the change in the energy of one component in a system (limited to two or three components) when the change in energy of the other component(s) and out of the system are known. • Use mathematical expressions and the concept of conservation of energy to predict and describe system behavior.

Modifications: *Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.(See NGSS Appendix D)*
• *Restructure lesson using UDL principles* (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA) • *Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.*

- *Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).*
- *Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).*
- *Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).*
- *Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.*
- *Use project-based science learning to connect science with observable phenomena.*
- *Structure the learning around explaining or solving a social or community-based issue.*
- *Provide ELL students with multiple literacy strategies.*
- *Collaborate with after-school programs or clubs to extend learning opportunities.*

Leveraging English Language Arts/Literacy and Mathematics

English Language Art/Literacy-

- Make strategic use of digital media in presentations to enhance understanding of the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Make strategic use of digital media in presentations to support the claim that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).
- Conduct short as well as more sustained research projects to describe energy conversions as energy flows into, out of, and within systems.
- Integrate and evaluate multiple sources of information presented in diverse formats and media to describe energy conversions as energy flows into, out of, and within systems.
- Evaluate scientific text regarding energy conversions to determine the validity of the claim that although energy cannot be destroyed, it can be converted into less useful forms.
- Compare different sources of information describing energy conversions to create a coherent understanding of energy flows into, out of, within, and between systems.

Mathematics-

- Represent symbolically an explanation about the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known, and manipulate the representing symbols. Make sense of quantities and relationships about 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 symbolically, and manipulate the representing symbols.
- Use a mathematical model to explain the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known. Identify important quantities in energy of components in systems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known; choose and interpret units consistently in formulas representing how the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known; choose and interpret the scale and the origin in graphs and data displays representing that the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Define appropriate quantities for the purpose of descriptive modeling of how the quantitative change in energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing how the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Represent symbolically that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and manipulate the representing symbols. Make sense of quantities and relationships between the energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).
- Represent the conversion of one form of energy into another symbolically, considering criteria and constraints, and manipulate the representing symbols. Make sense of quantities and relationships in the conversion of one form of energy into another.
- Use a mathematical model of how energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects). Identify important quantities representing how the energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use a mathematical model to describe the conversion of one form of energy into another and to predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the conversion of one form of energy into another and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the conversion of one form of energy into another; choose and interpret units consistently in formulas representing energy conversions as energy flows into, out of, and within systems; choose and interpret the scale and the origin in graphs and data displays representing energy conversions as energy flows into, out of, and within systems.

- Define appropriate quantities for the purpose of descriptive modeling of a device to convert one form of energy into another form of energy.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of energy conversions as energy flows into, out of, and within systems.

Samples of Open Education Resources for this unit:
Energy Skate Park: Basics:Learn about conservation of energy with a skater gal! Explore different tracks and view the kinetic energy, potential energy and friction as she moves. Build your own tracks, ramps, and jumps for the skater.

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PHYSICS Unit 3: Light and Optics (45 Instructional Days)	
Overarching Essential Questions	**Overarching Enduring Understandings**
● How can light be both a wave and a particle at the same time? ● How does light behave at the boundary between two mediums? ● Where, exactly, is the 'man in the mirror'? ● Does light ***always*** travel straight?	● Light is a form of electromagnetic radiation with a wavelength between 400 and 700 nm. It can act as both a wave and a particle, both of which explain certain phenomena associated with light. ● Properties of light include reflection, refraction, diffusion, and interference. ● Lenses and mirrors can be used to manipulate and harness light for many purposes common in the modern world.

Student Learning Objectives	
What students should be able to do after instruction.	*Evidence Statements*
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength,and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound	**HS-PS4-1**

waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]	
Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [*Assessment Boundary:* Assessment does not include using quantum theory.]	**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.[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]	**HS-PS4-4**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.(HS-PS4-3) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-PS4-4, HS-PS4-5) • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4)	**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) • Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3) **PS4.B: Electromagnetic Radiation** • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-PS4-3) **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1) • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4) ---

Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)	electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)	**Connections to Engineering, Technology, and Applications of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)

Embedded English Language Arts/Literacy and Mathematics	
English Language Arts/Literacy -	
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-3), (HS-PS4-4)
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-PS4-3), (HS-PS4-4)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1), (HS-PS4-4)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4)
Mathematics –	

MP.2	Reason abstractly and quantitatively. (HS-PS4-1), (HS-PS4-3)
MP.4	Model with mathematics. (HS-PS4-1)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1), (HS-PS4-3)
HSA-SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1), (HS-PS4-3)
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1), (HS-PS4-3)

Three-Dimensional Teaching and Learning

Prior Learning

Physical science-

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.
- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

Part A: How does an automatic door know when to open?

Concepts	Formative Assessment
• 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. • A wave model or a particle model (e.g., physical, mathematical, computer models) can be used to describe electromagnetic radiation—including	*Students who understand the concepts are able to:* • 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. • Use models (e.g., physical,mathematical,computer models) to simulate electromagnetic radiation systems and interactions—including energy,

energy, matter, and information flows—within and between systems at different scales.	matter,and information flows—within and between systems at different scales.

Part B: Why *are* objects closer than they appear?	
Concepts	**Formative Assessment**
• Light, and other forms of electromagnetic radiation, can be absorbed or reflected. There are certain laws governing the reflection of light off of both flat and curved surfaces. • By changing the shape of the surface doing the reflecting, a reflected light ray can be moved around with precision.	*Students who understand the concepts are able to:* • Give qualitative and quantitative descriptions of how light responds when reflecting off of different surfaces. • Use algebraic relationships to quantitatively describe relationships among incident and reflected light rays. • Use models (e.g., physical,mathematical,computer models) to simulate the path a light wave takes into and off of a mirror.

Part C: Why do even deep pools look so shallow?	
Concepts	**Formative Assessment**
• Light is just a small portion of the entire electromagnetic spectrum, but it behaves similarly to the other forms. There are, however, differences in how different types of electromagnetic radiation act when absorbed by matter. • 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. • The wavelength and frequency of a wave 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.	*Students who understand the concepts are able to:* • Evaluate the validity and reliability of multiple claims in published materials about the effects that different frequencies of electromagnetic radiation have when absorbed by matter. • Give qualitative and quantitative descriptions of how photons associated with different frequencies of light have different energies and how the behavior of the photon depends on the medium it is in. • Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. • Use algebraic relationships to quantitatively describe relationships among the frequency, wavelength, and speed of waves traveling in various media.

Modifications: *Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.(See NGSS Appendix D)*

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

Leveraging English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

- Cite textual evidence to support analysis of science and technical texts describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., qualitative data, video multimedia) in order to address the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Gather relevant information from multiple authoritative print and digital sources describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

Mathematics-

- Represent symbolically that electromagnetic radiation can be described either by a wave model or aparticle model and that for some situations one model is more useful than the other, and manipulate the representing symbols.
- Make sense of quantities and relationships between the wave model and the particle model of electromagnetic radiation.
- Interpret expressions that represent the wave model and particle model of electromagnetic radiation in terms of the usefulness of the model depending on the situation.
- Choose and produce an equivalent form of an expression to reveal and explain properties of electromagnetic radiation.
- Rearrange formulas representing electromagnetic radiation to highlight a quantity of interest, using the same reasoning as in solving equations.

Samples of Open Education Resources for this unit:

Introduction to the Electromagnetic Spectrum: NASA background resource

Radio Waves and Electromagnetic Fields: PHeT simulation demonstrating wave generation, propagation and detection with antennas.

Wave Interference: PHeT simulation of both mechanical and optical wave phenomena

Photoelectric Effect PHeT: PHeT simulation addressing evidence for particle nature of electromagnetic radiation

Interaction of Molecules with Electromagnetic Radiation: PHeT simulation exploring the effect of microwave, infrared, visible and ultraviolet radiation on various molecules.

Wave/Particle Dualism: PHeT simulation of wave and particle views of interference phenomena.

X-ray Technology: OSP Simulation of optimization of X-ray contrast by varying energy of X-rays, materials characteristics and measurement parameters

Wave on a string: Students will watch a wave on a string. Adjusting the amplitude, frequency, damping and tension will demonstrate wave properties.

Refraction through Glass:Students will trace the course of different rays of light through a rectangular glass slab at different angles of incidence, measure the angle of incidence, refraction, measure the lateral displacement to verify Snell`s law.

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