



Diocese of Alexandria ~ Catholic Schools

Where faith and knowledge grow



DIOCESE OF ALEXANDRIA

As the Diocese of Alexandria seeks to provide a comprehensive learning environment, we are charged to “Teach More” by showing how all learning flows from and relates to our Creator. In this way, we will give our teaching a deeper meaning and purpose than simply the content itself. With this as our goal, the Catholic Schools Office has intertwined our selected curricular standards with the Catholic Standards developed by the Cardinal Newman Society. Through the merging of these two curricula, English Language Arts, Mathematics, Science, and Social Studies, teachers will be provided a roadmap to guide student’s understanding and recognition of the relationship between learning and the connection to our God.

Thomas E. Roque, Sr.
Superintendent of Catholic Schools



DIOCESE OF ALEXANDRIA

Through comprehensive review of curricula from high performing districts throughout the United States in combination with parochial schools and Newman Cardinal Standards, the Curriculum Team for the Diocese of Alexandria has generated curricula for English Language Arts, Mathematics, Science, and Social Studies. The development of this framework is designed to guide the instructional path of teachers as they focus on the formation of their students in the areas of faith, academic excellence, responsible citizenry, and effective communication and collaboration. This process is a continuous improvement process with no defined beginning or end.

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Frameworks



THE DIOCESE
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HOW TO USE

The frameworks are guides to instruction. The frameworks assist teachers in planning and pacing instruction. Specific dates or weeks that may be included in this document are for reference. Each school and teacher must consider the make-up of their students, focusing on the needs and strengths of each child when pacing and planning instruction.

The cycles for the year help pace instruction and ensure students have consistent coverage of the content. The duration (the suggested amount of time to spend on each cycle) does not accommodate for the scheduling of special events, inclement weather or school events. Teachers, with principal guidance, should adjust pacing as needed to accommodate for these events.

RESEARCH-BASED HIGH-YIELD PRACTICES FOR INSTRUCTION

These strategies have proven effective in affecting student learning and achievement gains. As you plan daily instruction, consider how and where to integrate these strategies into the instructional sequence. Effect size is in parentheses. Please refer to the works of John Hattie for a complete description of instructional effect size.

- Classroom Discussion/Discourse (.82)
- Teacher Clarity/making the learning visible with expectations for learning (.75)
- Reciprocal Teaching (.74)
- Feedback (.73)
- Metacognitive Strategies (.69)

Physics



THE DIOCESE
of ALEXANDRIA

Unit 1: FORCES AND MOTION

Instructional Days: 25 days

SUMMARY

How can one explain and predict interactions between objects and within systems of objects?

In this unit of study, students are expected to *plan and conduct investigations, analyze data and using math to support claims, and apply scientific ideas to solve design problems* students in order to develop an understanding of ideas related to why some objects keep moving and some objects fall to the ground. Students will also build an understanding of forces and Newton's second law. Finally, they will develop an understanding that the total momentum of a system of objects is conserved when there is no net force on the system. Students are also able to apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. The crosscutting concepts of *patterns, cause and effect, and systems and systems models* are called out as organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *planning and conducting investigations, analyzing data and using math to support claims, and applying scientific ideas to solve design problems* and to use these practices to demonstrate understanding of the core ideas.

Student Learning Objectives

Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time. *[Clarification Statement: Students should be able to accurately move from one representation of motion to another.]* (PS2.A)

Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. (PS2.A)

Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations. (PS2.A)

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)

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)

Unit Sequence

Part A: How do they know how long the yellow light should be on before it turns red? (*traffic light*)

Concepts	Formative Assessment
<ul style="list-style-type: none"> Theories and laws provide explanations in science. 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. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> 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.

Unit Sequence	
Part B: How can a piece of space debris the size of a pencil eraser destroy the International Space Station?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • 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. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • 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.

Unit Sequence	
Part C: Red light cameras were placed in intersections to reduce the number of collisions caused by cars running red lights. Many people thought that they were unfair and demanded that they be removed. As an expert on the physics of moving bodies, you are challenged to engineer traffic signals to proactively reduce the number of people entering an intersection after the light turns red. The cost of the redesign must not exceed 10% of the current cost of current traffic signals or the energy needed to operate them.	
Concepts	Formative Assessments
<ul style="list-style-type: none"> • 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 and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and the criteria and constraints should be quantified to the extent possible and stated in such a way that one can 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. • Apply scientific ideas to solve a design problem for a device that minimizes the force on a macroscopic object during a collision, taking into account possible unanticipated effects.

<p>determine whether a given design meets them.</p> <ul style="list-style-type: none"> • 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. • 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. • Systems can be designed to cause a desired effect. 	<ul style="list-style-type: none"> • Use qualitative evaluations and /or algebraic manipulations to design and refine a device that minimizes the force on a macroscopic object during a collision.
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Sample of Open Education Resources
<p><u>Forces in One Dimension:</u> 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).</p> <p><u>Forces and Motion:</u> 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).</p> <p><u>Parachute and Terminal Velocity:</u> 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 <i>terminal velocity</i>.</p>

Appendix A: NGSS and Foundations for the Unit

Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time. *[Clarification Statement: Students should be able to accurately move from one representation of motion to another.]* (PS2.A)

Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. (PS2.A)

Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations. (PS2.A)

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)

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 performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Analyzing and Interpreting Data</p> <ul style="list-style-type: none"> 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) <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> Use mathematical representations of phenomena to describe explanations. (HS-PS2-2) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HSPS2-3) Design a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) Evaluate a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff 	<p>PS2.A: Forces and Motion</p> <ul style="list-style-type: none"> 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 in the momentum of objects outside the system. (HS-PS2-2) <p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> 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) <p>ETS1.C: Optimizing the Design Solution</p>	<p>Cause and Effect</p> <ul style="list-style-type: none"> 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) <p>Systems and System Models</p> <ul style="list-style-type: none"> When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) <p>Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World</p> <ul style="list-style-type: none"> 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) <p>Connections to Nature of Science</p>

<p>considerations. (HS-ETS1-3)</p>	<ul style="list-style-type: none">• 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. (secondary to (HS-PS2-3)) <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none">• 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)	<p>Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</p> <ul style="list-style-type: none">• Theories and laws provide explanations in science. (HS-PS2-1)• Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1)
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Physics



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Unit 2: FUNDAMENTAL FORCES

Instructional Days: 20 Days

SUMMARY

How can one explain and predict interactions between objects and within systems of objects?

In this unit of study, students plan and conduct investigations and apply scientific ideas to make sense of Newton's law of gravitation and Coulomb's Law. They apply these laws to describe and predict the gravitational and electrostatic forces between objects. The crosscutting concept of *patterns* is called out as an organizing concept for this disciplinary core idea. Students are expected to demonstrate proficiency in *planning and conducting investigations* and *applying scientific ideas* to demonstrate an understanding of core ideas.

Student Learning Objectives

Make predictions about the sign and relative quantity of net charge of objects or systems after various charging processes. (PS2.B)

Construct an explanation of a model of electric charge, and make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes. *[Clarification Statement: The focus is on the mechanisms that explain conductors and insulators.]* (PS2.B)

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)

Unit Sequence

Part A: Why are people on Earth stuck here while astronauts appear to be weightless?

How does the weight (force of gravity) of an astronaut of a specific mass (100 kg including gear) change at specific distances from Earth as the shuttle flies toward the moon?

Concepts

- Newton's Law of Universal Gravitation provides the mathematical models to describe and predict the effects of gravitational forces between distant objects.
- Forces at a distance are explained by fields (gravitational) permeating space that can transfer energy through space.
- 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 the gravitational force between objects.

Formative Assessment

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.
- Demonstrate how Newton's Law of Universal Gravitation provides explanations for observed scientific phenomena.
- Observe patterns at different scales to provide evidence for gravitational forces between two objects in a system with two objects.

Unit Sequence

Part B: How far away can my finger be from my sister or brother if I want to zap them with static electricity?

Concepts

- Coulomb's Law provides the mathematical models to describe and predict the effects of electrostatic forces between distant objects.
- Forces at a distance are explained by fields (electric and magnetic) that permeate space and can transfer energy through space.
- Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- 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 electrostatic attraction and repulsion.

Formative Assessment

Students who understand the concepts are able to:

- Use mathematical representations of phenomena to describe or explain how electrostatic force is proportional to charge and inversely proportional to distance squared.
- Use mathematical representations of Coulomb's Law to predict the electrostatic forces between two objects in systems with two objects.
- Observe patterns at different scales to provide evidence for electrostatic forces between two objects in systems with two objects.

Sample of Open Education Resources

[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.

[Graphical Relationships in Electric Fields](#): Activity uses the simulations to generate data to be analyzed. Allows for graphical analysis and equations related to voltage and Coulombs Law.

[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.

Appendix A: NGSS and Foundations for the Unit

The performance expectations above were developed using the following elements from the NRC document
A Framework for K-12 Science Education:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>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.</p> <ul style="list-style-type: none"> Use mathematical representations of phenomena to describe explanations. (HS-PS2-4) 	<p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> 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) 	<p>Patterns</p> <ul style="list-style-type: none"> 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) <p>Connections to Nature of Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</p> <ul style="list-style-type: none"> Theories and laws provide explanations in science. (HS-PS2-4) Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-4)

Physics



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Unit 3: KEPLER'S LAWS

Instructional Days: 15 Days

SUMMARY

How was it possible for NASA to intentionally fly into Comet Tempel 1?

In this unit of study, students *use mathematical and computational thinking* to examine the processes governing the workings of the solar system and universe. The crosscutting concepts of *scale, proportion, and quantity* are called out as organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *using mathematical and computational thinking* and to use this practice to demonstrate understanding of core ideas.

Student Learning Objectives

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)*

Unit Sequence

Part A: How was it possible for NASA to intentionally fly into Comet Tempel 1?

Concepts

- 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.
- 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).

Formative Assessment

- 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.

Sample of Open Education Resources

- [Planetary Orbits Lab](#) - Understanding and utilizing Kepler's laws of motion plus the effects of velocity and force on a satellites' orbit
- [Gravity Force Lab](#) - Students will use the Gravity Force Lab PhET Simulation to investigate what the gravitational force between two objects depends on and experimentally determine the Universal Gravitational constant, G. [Lab Sheet](#)
- [Period of Jupiter's moons](#) - Students use a series of 31 images of Jupiter's 4 Galilean moons to find their orbit periods and orbit radii. They compare their results with known data for those moons. Finally they test various mathematical expressions to find a "constant" relationship between orbit period (T) and orbit radius (R) to arrive at Kepler's 3rd Law. ([All activities Kepler's NASA](#))
- [Periodic Planetary Orbits](#) - This activity will show how to calculate the period of the orbit (length of the year) for planets in the Solar System.
- [Curtate of Planetary Orbits](#) - Calculate and plot orbits of Planets in Solar System
- [Exploring Kepler's Laws and the Universal Law of Gravitation](#) - Using Interactive Physics to explore **Kepler's laws of planetary motion** and the universal **law** of gravitation.
- [Basic Kepler Activity](#) - This activity will discuss the properties of ellipses and Kepler's laws of orbital motion.

Appendix A: NGSS and Foundations for the Unit

The performance expectations above were developed using the following elements from the NRC document
[*A Framework for K-12 Science Education:*](#)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematical and Computational Thinking</p> <ul style="list-style-type: none"> Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4) 	<p>ESS1.B: Earth and the Solar System</p> <p>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)</p>	<p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> 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) <p>Connection to Engineering, Technology, and Applications of Science</p> <p>Interdependence of Science, Engineering, and Technology</p> <p>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)</p>

Physics



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Unit 4: Energy

Instructional Days: 25 Days

SUMMARY

How is energy transferred and conserved?

In this unit of study, students *develop and use models, plan and carry out investigations, use computational thinking and design solutions* as they make sense of the disciplinary core idea. The disciplinary core idea of *Energy* is broken down into subcore ideas: *definitions of energy, conservation of energy and energy transfer, and the relationship between energy and forces*. Energy is understood as a quantitative property of a system that depends on the motion and interactions of matter, and the total change of energy in any system is equal to the total energy transferred into and out of the system. Students also demonstrate their understanding of engineering principles when they design, build, and refine devices associated with the conversion of energy. The crosscutting concepts of *cause and effect, systems and systems models, energy and matter, and the influence of science, engineering, and technology on society and the natural world* are further developed in the performance expectations. Students are expected to demonstrate proficiency in *developing and using models, planning and carry out investigations, using computational thinking and designing solutions*, and they are expected to use these practices to demonstrate understanding of core ideas.

Student Learning Objectives

Identify and quantify the various types of energies within a system of objects in a well-defined state, such as elastic potential energy, gravitational potential energy, kinetic energy, and thermal energy and represent how these energies may change over time. (PS3.A and PS3.B)

Calculate changes in kinetic energy and gravitational potential energy of a system using representations of that system. (PS3.A)

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). *[Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]* (HS-PS3-2)

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)**

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. * *[Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]* **(HS-PS3-3)**

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)**

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)**

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)**

Unit Sequence

Part A: I have heard about it since kindergarten but what is energy?

Concepts

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- 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).
- Radiation is a phenomenon in which energy stored in fields moves across spaces.
- Energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems.

Formative Assessment

Students who understand the concepts are able to:

- Develop and use models based on evidence to illustrate 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).
- 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.

Unit Sequence

Part B: How can we use mathematics to prove what happens in an abiotic and biotic systems?

Concepts

- 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.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- 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.

Formative Assessment

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.

Unit Sequence

Part C: Superstorm Sandy devastated the New Jersey Shore and demonstrated to the public how vulnerable our infrastructure is. Using your understandings of energy, design a low technology system that would insure the availability of energy to residents if catastrophic damage to the grid occurs again.

Concepts

- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- 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.
- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
- News 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.
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water or for energy sources that minimize pollution that can be addressed through engineering. These global challenges also may have manifestations in local communities.

Formative Assessment

Students who understand the concepts are able to:

- Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Analyze a device to convert one form of energy into another form of energy by specifying criteria and constraints for successful solutions.
- Use mathematical models and/or computer simulations to predict the effects of a device that converts one form of energy into another form of energy.

Sample of Open Education Resources

[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.

[Work and Energy Workbook Labs](#): The lab description pages describe the question and purpose of each lab and provide a short description of what should be included in the student lab report.

[Build a Solar House](#): Construct and measure the energy efficiency and solar heat gain of a cardboard model house. Use a light bulb heater to imitate a real furnace and a temperature sensor to monitor and regulate the internal temperature of the house. Use a bright bulb in a gooseneck lamp to model sunlight at different times of the year, and test the effectiveness of windows for passive solar heating.

Appendix A: NGSS and Foundations for the Unit

The performance expectations above were developed using the following elements from the NRC document

[*A Framework for K-12 Science Education*](#)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Developing and Using Models</p> <ul style="list-style-type: none"> Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2) <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3) <p>Asking Questions and Defining Problems</p>	<p>PS3.A: Definitions of Energy</p> <ul style="list-style-type: none"> 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 	<p>Systems and System Models</p> <ul style="list-style-type: none"> 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) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (HS-ETS1-4) <p>Energy and Matter</p> <ul style="list-style-type: none"> 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) <p style="text-align: center;"><i>Connections to Engineering, Technology, and Applications of Science</i></p>

<ul style="list-style-type: none"> Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> 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) 	<p>radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)</p> <p>PS3.B: Conservation of Energy and Energy Transfer</p> <ul style="list-style-type: none"> 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 predict and describe system behavior. (HS-PS3-1) The availability of energy limits what can occur in any system. (HS-PS3-1) <p>PS3.D: Energy in Chemical Processes</p> <ul style="list-style-type: none"> Although energy cannot be destroyed, it can be converted to less useful forms—for example, 	<p>Influence of Science, Engineering and Technology on Society and the Natural World</p> <ul style="list-style-type: none"> Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3) New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3) <p><i>Connections to Nature of Science</i></p> <p>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</p> <ul style="list-style-type: none"> Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)
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to thermal energy in the surrounding environment. (HS-PS3-3)

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (*secondary to HS-PS3-3*)

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local

communities. (HS-ETS1-1)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)

Physics



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Unit 5: THE PHYSICS OF THE GEOSPHERE

Instructional Days: 15 Days

SUMMARY

How much force and energy is needed to move a continent?

In this unit of study, students construct explanations for the scales of time over which Earth processes operate. An important aspect of Earth and space sciences involves making inferences about events in Earth's history based on a data record that is increasingly incomplete the farther one goes back in time. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record. Students develop *models and explanations* for the ways that feedback among different Earth systems controls the appearance of the Earth's surface. Central to this is the tension between internal systems, which are largely responsible for creating land at Earth's surface (e.g., volcanism and mountain building), and the sun-driven surface systems that tear down land through weathering and erosion. Students demonstrate proficiency in *developing and using models, constructing explanations, and engaging in argument from evidence*. The crosscutting concepts of *stability and change, energy and matter, and patterns* are called out as organizing elements of this unit.

Student Learning Objectives

Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. *[Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).]* *[Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.]* **(HS-ESS2-1)**

Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. *[Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]* **(HS-ESS2-3)**

Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. *[Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).]* **(HS-ESS1-5)**

Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems. *[Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth’s surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]* **(HS-ESS2-2)**

Unit Sequence

Part A: How long does it take to make a mountain?

Concepts	Formative Assessment
<ul style="list-style-type: none"> • Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. • Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth’s crust. • Change and rates of change can be quantified and modeled over very short or very long periods of time. • Some system changes are irreversible. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. • Develop a model to illustrate how the appearance of land features and sea-floor features are a result of both constructive forces and destructive mechanisms. • Quantify and model rates of change of Earth’s internal and surface processes over very short and very long periods of time.

Unit Sequence

Part B: How much force is needed to move a continent? What can possibly provide the energy for that much force?

Concepts

- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of
- Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust.
- Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.
- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.
- Energy drives the cycling of matter within and between Earth's systems.
- 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.
- Science knowledge is based on empirical evidence.

Formative Assessment

Students who understand the concepts are able to:

- Develop an evidence-based model of Earth's interior to describe the cycling of matter by thermal convection.
- Develop a one-dimensional model, based on evidence, of Earth with radial layers determined by density to describe the cycling of matter by thermal convection.
- Develop a three-dimensional model of Earth's interior, based on evidence, to show mantle convection and the resulting plate tectonics.
- Develop a model of Earth's interior, based on evidence, to show that energy drives the cycling of matter by thermal convection.

<ul style="list-style-type: none"> • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. • Science includes the process of coordinating patterns of evidence with current theory. 	
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Unit Sequence	
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Part C: Are all rocks the same age?	
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Concepts	Formative Assessment
<ul style="list-style-type: none"> • Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. • Spontaneous radioactive decay follows a characteristic exponential decay law. • Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. • Empirical evidence is needed to identify patterns in crustal rocks. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. • Evaluate evidence of plate interactions to explain the ages of crustal rocks.

Unit Sequence

Part D: How do changes in the geosphere effect the atmosphere?

Concepts	Formative Assessment
<ul style="list-style-type: none">• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.• The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.• Feedback (negative or positive) can stabilize or destabilize a system.• 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.	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none">• Analyze geoscience data using tools, technologies, and/or models (e.g., computational, mathematical) to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

Sample of Open Education Resources

[EarthViewer \(IPAd or Android\)](#) or for [Chrome](#) browsers: Students explore the co-evolution of the geology and biology found on Earth to develop arguments from evidence for the co-evolution of geology and biology found on Earth. If IPads, Androids or Chrome browsers are not available, similar interactives may be found at this [link](#), and this [link](#).

[Earth Systems Activity](#): Students model the carbon cycle and its connection with Earth's climate.

[Greenhouse Effect](#): Students explore the atmosphere during the ice age and today. What happens when you add clouds? Change the greenhouse gas concentration and see how the temperature changes. Then compare to the effect of glass panes. Zoom in and see how light interacts with molecules. Do all atmospheric gases contribute to the greenhouse effect?

Appendix A: NGSS and Foundations for the Unit

The performance expectations above were developed using the following elements from the NRC document

[*A Framework for K-12 Science Education:*](#)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Developing and Using Models</p> <ul style="list-style-type: none"> Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1),(HS-ESS2-3) <p>Analyzing and Interpreting Data</p> <ul style="list-style-type: none"> 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-ESS2-2) <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5) 	<p>ESS2.A: Earth Materials and Systems</p> <ul style="list-style-type: none"> Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-1),(HS-ESS2-2) Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth’s surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth’s interior and gravitational movement of denser materials toward the interior. (HS-ESS2-3) <p>ESS2.B: Plate Tectonics and Large-Scale System Interactions</p> <ul style="list-style-type: none"> The radioactive decay of unstable isotopes continually generates new energy within Earth’s crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of 	<p>Energy and Matter</p> <ul style="list-style-type: none"> Energy drives the cycling of matter within and between systems. (HS-ESS2-3) Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1) Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2) <p>Patterns</p> <ul style="list-style-type: none"> Empirical evidence is needed to identify patterns. (HS-ESS1-5) <p><i>Connections to Engineering, Technology, and Applications of Science</i></p> <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> 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-ESS2-3)

	<p>mantle convection. (HS-ESS2-3)</p> <ul style="list-style-type: none"> • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (HS-ESS2-1) <p>ESS2.D: Weather and Climate</p> <ul style="list-style-type: none"> • The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2) <p>ESS1.C: The History of Planet Earth</p> <ul style="list-style-type: none"> • Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS-ESS1-5) 	<p>Influence of Engineering, Technology, and Science on Society and the Natural World</p> <ul style="list-style-type: none"> • 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-ESS2-2) <p>Scientific Knowledge is Based on Empirical Evidence</p> <ul style="list-style-type: none"> • Science knowledge is based on empirical evidence. (HS-ESS2-3) • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-3) <p>Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3)</p>
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Physics



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Unit 6: WAVE PROPERTIES

Instructional Days: 20Days

SUMMARY

How are waves used to transfer energy and send and store information?

In this unit of study, students apply their understanding of how wave properties can be used to transfer information across long distances, store information, and investigate nature on many scales. The crosscutting concept of *cause and effect* is highlighted as an organizing concept for these disciplinary core ideas. Students are expected to demonstrate proficiency in *using mathematical thinking*, and to use this practice to demonstrate understanding of the core idea.

Student Learning Objectives

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)*

Unit Sequence

Part A Why do physicists make the best surfers? How do we know what the inside of the Earth looks like?

Concepts

- 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.
- Empirical evidence is required to differentiate between cause and correlation and to make a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Formative Assessment

Students who understand the concepts are able to:

- 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.

Sample of Open Education Resources

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

Slinky Lab: Students will observe patterns of waves and their interactions using a slinky.

Ripple Tank: Students will investigate wave properties (speed in a medium, reflection, diffraction, interference) using the PhET virtual ripple tank, or use an actual [ripple tank](#).

Resonance Tube: Velocity of Sound. Students will observe the resonance phenomenon in an open ended cylindrical tube, and use the resonance to determine the velocity of sound in air at ordinary temperatures.

Resonance: Students will identify, through experimentation, cause and effect relationships that affect natural resonance of these systems.

Sound Waves: Students will adjust the frequency to both see and hear how the wave changes to explain how different sounds are modeled, described, and produced.

Doppler Effect: Students will explore the detection of sound waves from a moving source and the change in frequency of the detected wave via the Doppler effect.

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.

Appendix A: NGSS and Foundations for the Unit

The performance expectations above were developed using the following elements from the NRC document [*A Framework for K-12 Science Education*](#):

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking</p> <p>Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)</p>	<p>PS4.A: Wave Properties</p> <ul style="list-style-type: none">• 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)	<p>Cause and Effect</p> <p>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)</p>

Physics



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Unit 7: ELECTROMAGNETIC RADIATION

Instructional Days: 30 Days

SUMMARY

Why has digital technology replaced analog technology?

In this unit of study, students are able to apply their understanding of wave properties to make sense of how electromagnetic radiation can be used to transfer information across long distances, store information, and be used to investigate nature on many scales. Models of electromagnetic radiation as both a wave of changing electrical and magnetic fields or as particles are developed and used. Students also demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. The crosscutting concepts of *systems and system models; stability and change; interdependence of science, engineering, and technology; and influence of engineering, technology, and science on society and the natural world* are highlighted as organizing concepts. Students are expected to demonstrate proficiency in *asking questions, engaging in argument from evidence, and obtaining, evaluating, and communicating information*, and they are expected to use these practices to demonstrate understanding of the core ideas.

Student Learning Objectives

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)**

Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.* *[Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]* **(HS-PS4-5)**

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **(HS-ETS1-1)**

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. **(HS-ETS1-3)**

Evaluate questions about the advantages of using a digital transmission and storage of information. *[Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]* **(HS-PS4-2)**

Unit Sequence

Part A: How can electromagnetic radiation be both a wave and a particle at the same time?

Concepts

- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- A wave model or a particle model (e.g., physical, mathematical, computer models) can be used to describe electromagnetic radiation—including energy, matter, and information flows—within and between systems at different scales.
- A wave model and a particle model of electromagnetic radiation are based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Formative Assessment

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.
- Evaluate experimental evidence 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.

Unit Sequence

Part B: Should we encourage the board of education to install solar panels?

Concepts

- 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.
- Cause-and-effect relationships can be suggested and predicted for electromagnetic radiation systems when matter absorbs different frequencies of light by examining what is known about smaller scale mechanisms within the system.

Formative Assessment

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.
- Evaluate the validity and reliability of claims that photons associated with different frequencies of light have different energies and that the damage to living tissue from electromagnetic radiation depends on the energy of the radiation.
- Give qualitative descriptions of how photons associated with different frequencies of light have different energies and how the damage to living tissue from electromagnetic radiation depends on the energy of the radiation.
- Suggest and predict cause-and-effect relationships for electromagnetic radiation systems when matter absorbs different frequencies of light by examining what is known about smaller scale mechanisms within the system.

Unit Sequence

Part C: How does the International Space Station power all of its equipment? How do astronauts communicate with people on the ground?

Concepts

- Solar cells are human-made devices that capture the sun's energy and produce electrical energy.
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- Photoelectric materials emit electrons when they absorb light of a high enough frequency.
- 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.
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water and food and for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.
- When evaluating solutions, it is important to take into account a range of constraints, including cost,

Formative Assessment

Students who understand the concepts are able to:

- Communicate qualitative technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- Communicate technical information or ideas about technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy in multiple formats (including orally, graphically, textually, and mathematically).
- Analyze technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy by specifying criteria and constraints for successful solutions.
- Evaluate a solution offered by technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

- Wave interaction with matter systems can be designed to transmit and capture information and energy.
- Science and engineering complement each other in the cycle known as research and development (R&D).
- Modern civilization depends on major technological systems.
- 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.

Unit Sequence

Part D: How does my hard drive store information?

Concepts

- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- Systems for transmission and storage of information can be designed for greater or lesser stability.
- Modern civilization depends on systems for transmission and storage of information.
- Engineers continuously modify these technological systems for transmission and storage of information by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Formative Assessment

Students who understand the concepts are able to:

- Evaluate questions about the advantages of using digital transmission and storage of information by challenging the premise of the advantages of digital transmission and storage of information, interpreting data, and considering the suitability of digital transmission and storage of information.
- Consider advantages and disadvantages in the use of digital transmission and storage of information.

Sample of Open Education Resources

[Introduction to the Electromagnetic Spectrum](#): NASA background resource

[Technology for Imaging the Universe](#): NASA background resource

[NASA LAUNCHPAD: Making Waves](#): NASA e-Clips activity on the electromagnetic spectrum

[Radio Waves and Electromagnetic Fields](#): Phet simulation demonstrating wave generation, propagation and detection with antennas.

[Refraction](#): <https://phet.colorado.edu/en/simulation/wave-interference> PHeT simulation addressing refraction of light at an interface.

[Wave Interference](#): Phet simulation of both mechanical and optical wave phenomena

[Thin Film Interference](#): OSP simulation of thin film interference for various wavelengths of visible light

[Photoelectric Effect Phet](#): Phet simulation addressing evidence for particle nature of electromagnetic radiation

[Photoelectric Effect](#) OSP: Open Source Physics simulation of the photoelectric effect.

[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

Appendix A: NGSS and Foundations for the Unit

The performance expectations above were developed using the following elements from the NRC document

[*A Framework for K-12 Science Education:*](#)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3) <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4) Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS4-5) <p>Asking Questions and Defining Problems</p> <ul style="list-style-type: none"> Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or 	<p>PS4.A: Wave Properties</p> <ul style="list-style-type: none"> 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) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-5) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2) <p>PS4.B: Electromagnetic Radiation</p> <ul style="list-style-type: none"> Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as 	<p>Systems and System Models</p> <ul style="list-style-type: none"> 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) <p>Cause and Effect</p> <ul style="list-style-type: none"> 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) Systems can be designed to cause a desired effect. (HS-PS4-5) <p>Stability and Change</p> <ul style="list-style-type: none"> Systems can be designed for greater or lesser stability. (HS-PS4-2) <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5) <p>Influence of Engineering, Technology, and Science on Society and the Natural World</p>

the suitability of a design. (HS-PS4-2)

Constructing Explanations and Designing Solutions

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

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)
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

PS3.D: Energy in Chemical Processes

- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary to HS-PS4-5)

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information

- Modern civilization depends on major technological systems. (HS-PS4-5, HS-PS4-2)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-3)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HSPS4-2)

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

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)

	<p>contained in them. (HS-PS4-5)</p> <p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none">• 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. (HS-ETS1-1)• Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none">• 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)	
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Physics



THE DIOCESE
of ALEXANDRIA

Unit 8: ELECTRICITY AND MAGNETISM

Instructional Days: 15 Days

SUMMARY

How can one explain and predict the interactions between objects and within a system of objects?

In this unit of study, students' understanding of how forces at a distance can be explained by fields, why some materials are attracted to each other while others are not, how magnets or electric currents cause magnetic fields, and how charges or changing magnetic fields cause electric fields. The crosscutting concept of *cause and effect* is called out as an organizing concept. Students are expected to demonstrate proficiency *in planning and conducting investigations and developing and using models*.

Student Learning Objectives

Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. *[Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.] (HS-PS2-5)*

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)*

Unit Sequence

Part A: What are the relationships between electric currents and magnetic fields?

Concepts	Formative Assessment
<ul style="list-style-type: none">• 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.• “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents.• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none">• Plan and conduct an investigation individually and collaboratively to produce data that can serve as the basis for evidence that an electric current can produce a magnetic field.• Plan and conduct an investigation individually and collaboratively to produce data that can serve as the basis for evidence that a changing magnetic field can produce an electric current.• In experimental design, decide on the types, amounts, and accuracy of data needed to produce reliable measurements, consider limitations on the precision of the data, and refine the design accordingly.• Collect empirical evidence to support the claim that an electric current can produce a magnetic field.• Collect empirical evidence to support the claim that a changing magnetic field can produce an electric current.

Unit Sequence

Part B: How can I exert a force on an object when I can't touch it?

Concepts	Formative Assessment
<ul style="list-style-type: none">• When two objects interacting through a field change relative position, the energy stored in the field is changed.• Cause-and-effect relationships between electrical and magnetic fields can be predicted through an understanding of inter- and intra-molecular forces (protons and electrons).	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none">• Develop and use an evidence-based 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.• Suggest and predict cause-and-effect relationships for two objects interacting through electric or magnetic fields.

Sample of Open Education Resources

[Magnets and Electromagnets](#): Explore the interactions between a compass and bar magnet. Discover how you can use a battery and wire to make a magnet! Can you make it a stronger magnet? Can you make the magnetic field reverse?

[Charges and Fields](#): Move point charges around on the playing field and then view the electric field, voltages, equipotential lines, and more.

[Faraday's Law](#): Investigate Faraday's law and how a changing magnetic flux can produce a flow of electricity!

Appendix A: NGSS and Foundations for the Unit

Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. *[Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]* **(HS-PS2-5)**

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)**

The performance expectations above were developed using the following elements from the NRC document [*A Framework for K-12 Science Education:*](#)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5) <p>Developing and Using Models</p> <p>Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS-PS3-5)</p>	<p>PS2.B: Types of Interactions</p> <ul style="list-style-type: none"> Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-5) <p>PS3.C: Relationship between Energy and Forces</p> <ul style="list-style-type: none"> When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5) 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-5) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS3-5)