Highland Park Public School District

435 Mansfield Street
Highland Park, New Jersey 08904

Curriculum Guide- Science - Environmental

Version 1
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Mastery Skills

Students will be able to understand, explain, and apply the following concepts and skills upon completion of this course:

Skill	Standard (if applicable)
Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.	**HS-ESS1-1**
Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	**HS-ESS1-2**
Communicate scientific ideas about the way stars over their life cycle, produce elements.	**HS-ESS1-3**
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	**HS-ESS1-4**
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.	**HS-ESS1-5**
Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.	**HS-ESS1-6**
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.	**HS-ESS2-1**
Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	**HS-ESS2-2**
Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	**HS-ESS2-3**
Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	**HS-ESS2-4**
Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	**HS-ESS2-5**
Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	**HS-ESS2-6**
Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.	**HS-ESS2-7**

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	**HS-ESS3-1** **HS-ESS3-2** **HS-ESS3-3** **HS-ESS3-4** **HS-ESS3-5** **HS-ESS3-6**
Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. 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. 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-ETS1-1** **HS-ETS1-2** **HS-ETS1-3** **HS-ETS1-4**

Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.	**HS-LS4-6**
Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.	**HS-PS1-8**
Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.	**HS-PS2-1**
Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	**HS-PS2-2**
Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	**HS-PS2-4**
Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	**HS-PS2-5**
Create a computational model to calculate the changes in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	**HS-PS3-1**
Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).	**HS-PS3-2**
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	**HS-PS3-3**
Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	**HS-PS3-5**
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	**HS-PS4-1**
Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more	**HS-PS4-3**

useful than the other.	
Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.	**HS-PS4-4**
Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.	**HS-PS4-5**

Scope and Sequence

Environmental - Earth

Unit	Unit	Unit	Unit
Chemistry of the Universe Weeks 1-5, 25 days	**Planetary Motion** Weeks 6-8, 10 days	**Physics of the Earth System** Weeks 9-13, 25 days	**Dynamic Earth Systems** Weeks 14-18, 25 days
Unit Description: All over the Universe stars work as giant reprocessing plants taking light chemical elements and transforming them into heavier ones. The composition of the Universe is studied in such fine detail because it is one of the keys to our understanding of processes in the very early Universe.	***Unit Description:*** What is happening in the sky? Students will examine the processes governing the motions of solar system objects.	***Unit Description:*** The Earth system is often represented by interlinking and interacting "spheres" of physical, chemical and biological processes. These spheres include the atmosphere, hydrosphere, biosphere and geosphere.	***Unit Description:*** There are many interacting systems that make up the Earth, many of which are constantly changing (dynamic). How do these changes in the Earth's systems affect life on Earth?
Unit Objectives: HS-ESS1-1 HS-ESS1-2 HS-ESS1-3 HS-ESS1-6 HS-PS1-8	***Unit Objectives:*** HS-ESS1-4 *HS-PS2-2* (*secondary to HS-ESS1-4*) *HS-PS2-4* (*secondary to HS-ESS1-4*)	***Unit Objectives:*** HS-ESS1-5 HS-ESS2-1 HS-ESS2-3 *HS-PS2-5* (*secondary to HS-ESS2-3*) *HS-PS4-1* (*secondary to HS-ESS2-3*) HS-PS2-1	***Unit Objectives:*** HS-ESS2-2 HS-ESS2-5 HS-ESS2-6 HS-ESS2-7

Scope and Sequence

Environmental - Sustainability

Unit	Unit	Unit
Human Activity & the Climate System Weeks 1-7, 30 days	**Human Activity & Sustainability** Weeks 8-12, 30 days	**Human Activity & Energy** Weeks 13-18, 30 days
Unit Description: Human activities contribute to climate change by causing changes in Earth's atmosphere. The largest known contribution comes from the burning of fossil fuels.	***Unit Description:*** Human activities can be direct threats to ecosystems. They can cause destruction, degradation, and the impairment of biodiversity and other natural resources. Sustainability implies preserving the overall balance of human activities with the ecosystem, respecting the environment, and preventing the exhaustion of natural resources.	***Unit Description:*** The impact that human beings have made on the Earth in terms of production and consumption of natural resources has formed a pattern in the planet's global energy flow. While addressing the environmental, social and economic impacts of energy consumption, we will also seek solutions for energy demand reduction, energy efficiency improvement, increases in renewable energy sources, technological progress and behavioral change in the field of energy.
Unit Objectives: HS-ESS2-4 HS-ESS3-5 *HS-ESS2-2* (*secondary to HS-ESS2-4*) *HS-ESS1-4* (*secondary to HS-ESS2-4*) *HS-ESS2-6* (*secondary to HS-ESS3-5*) *HS-PS4-4* (*secondary to HS-ESS2-4*)	***Unit Objectives:*** HS-ESS3-1 HS-ESS3-3 HS-ESS3-4 HS-ESS3-6 HS-ETS1-3 *HS-LS4-6* (*secondary to*HS-ESS3-4)	***Unit Objectives:*** HS-ESS3-2 HS-ETS1-1 HS-ETS1-2 HS-ETS1-4 HS-PS3-1 HS-PS3-2 HS-PS3-3 *HS-PS3-5* (*secondary to HS-PS3-3*) HS-PS4-3 HS-PS4-5

Unit Description

Unit Title
Chemistry of the Universe
Unit Summary
Energy and matter are studied further by investigating the processes of nuclear fusion and fission that govern the formation, evolution, and workings of the solar system in the universe. Students examine the processes governing the formation, evolution, and workings of the solar system and universe.
Learning Objectives Based on Mastery Skills
HS-ESS1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. **HS-ESS1-2:** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. **HS-ESS1-3:** Communicate scientific ideas about the way stars, over their life cycle, produce elements. **HS-ESS1-6:** Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. **HS-PS1-8:** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
Essential Questions
Why fusion is considered the Holy Grail for the production of electricity? Why aren't all forms of radiation harmful to living things? How do stars produce elements? Is the life span of a star predictable? If there was nobody there to Tweet about it, how do we know that there was a Big Bang? How can chemistry help us to figure out ancient events?
Evidence of Learning
Disciplinary Core Ideas **PS1.C: Nuclear Processes** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) **ESS1.A: The Universe and Its Stars** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3) The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2) Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2),(HS-ESS1-3) **ESS1.C: The History of Planet Earth** Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of

the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (HS-ESS1-6)

PS3.D: Energy in Chemical Processes and Everyday Life

Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary) (HS-ESS1-1)

PS4.B: Electromagnetic Radiation

Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.(secondary)HS-ESS1-2)

Required Lesson Activities (Assessment)

Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Use simple qualitative models based on evidence to illustrate the scale of energy released in nuclear processes relative to other kinds of transformations.

Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays

Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about the way stars, over their life cycles, produce elements.

Communicate scientific ideas about the way nucleosynthesis, and therefore the different elements it creates, vary as a function of the mass of a star and the stage of its lifetime.

Communicate scientific ideas about how in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core in releasing energy that eventually reaches Earth in the form of radiation.

Develop a model based on evidence to illustrate the relationships between nuclear fusion in the sun's core and radiation that reaches Earth.

Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

Construct an explanation of the Big Bang theory based on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars).

Construct an explanation based on valid and reliable evidence that energy in the universe cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems.

Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.

Use available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago.

Apply scientific reasoning to link evidence from ancient Earth materials, meteorites, and other planetary surfaces to claims about Earth's formation and early history, and assess the extent to which the reasoning and data support the explanation or conclusion.

Use available evidence within the solar system to construct explanations for how Earth has changed and how it remains stable.

Resources

Tarbuck, Edward J., Frederick K. Lutgens, and Dennis Tasa. *Pearson Earth Science*. Boston, MA: Pearson, 2011.

"Model Curriculum: Unit 1A: Chemistry of the Universe." *Model Curriculum: Unit 1A: Chemistry of the Universe*. Web. 15 July 2016.
http://www.state.nj.us/education/modelcurriculum/sci/capstoneu1a.shtml
Solar Fusion: Students develop a model to identify and describe the hydrogen as the Sun's fuel source, helium and energy as the products of nuclear fusion, and the life span of the Sun.
http://genesismission.jpl.nasa.gov/science/mod3_SunlightSolarHeat/FusionChemistry/
Expansion of the Universe & Four Pillars of Cosmology: Student analyze informational text, animations and videos on the Doppler effect and the observed redshift in the universe. Students apply their learning of the Doppler effect to justify the Big Bang Theory and support their reasoning with evidence from multiple sources.
http://www.ck12.org/earth-science/Expansion-of-the-Universe/lesson/Expansion-of-the-Universe-HS-ES/
http://www.damtp.cam.ac.uk/research/gr/public/bb_pillars.html
Extensions:
Sonic Boom Link: http://www.ck12.org/physics/Doppler-Effect/rwa/Sonic-Boom/
Echolocation Link: http://www.ck12.org/physics/Doppler-Effect/rwa/Echolocation/
Universe Evolution & CMB Analyzer: Students analyze several NASA concept animations to develop an explanation for the existence of background radiation and the redshift to defend the argument that the universe is expanding. http://wmap.gsfc.nasa.gov/media/030651/index.html
Life Cycle of a Star - Students analyze multiple sources of information text and diagrams on the life cycle of a star. Students use the text to determine the relationship between the stars' mass, life cycle and ability to fuse elements and ability to go spread the elements through the universe. http://www.ck12.org/earth-science/Life-Cycles-of-Stars/lesson/The-Life-Cycle-of-a-Star-PHYS/
Emission Spectrum of the Sun - Students analyze informational text and a video on how scientists know the composition of the sun. Students use the information to develop a written argument on how scientists can use this method to determine the composition of distant stars.
http://www.ck12.org/chemistry/Wavelength-and-Frequency-Calculations/rwa/Deciphering-the-Sun/
Interactive HR Diagram - Students manipulate the variables of the HR diagram to determine the relationship between the mass, lifespan, color and size of a star. Students generate conclusion between the mass and the lifespan of the star supported with data from the activity.
Supernova - Students analyze informational text regarding supernova to determine where a supernova takes place, the cause of supernovas and the role of supernovas in the evolution of the universe.
http://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-a-supernova.html

Science and Engineering Practices	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8),(HS-ESS1-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2) Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6) **Obtaining, Evaluating, and Communicating Information** Communicate scientific 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-ESS1-3) Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-ESS1-6)	**Energy and Matter** In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3), (HS-PS1-8), (HS-ESS1-1) Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2) **Scale, Proportion, and Quantity** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1) 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) In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) **Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6) ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2) ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2) Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2) **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 and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-2)

Unit Description

Unit Title
Planetary Motion
Unit Summary
Students use mathematical and computational thinking to examine the processes governing the motions of solar system objects. While doing so they plan and conduct investigations and apply scientific ideas to make sense of Newton's law of gravitation to describe and predict the gravitational forces between objects.
Learning Objectives Based on Mastery Skills
HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. ***HS-PS2-2*** **(*secondary to HS-ESS1-4*):** Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. ***HS-PS2-4*** **(*secondary to HS-ESS1-4*):** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
Essential Questions
How was it possible for NASA to intentionally fly into Comet Tempel 1?
Evidence of Learning
Disciplinary Core Ideas **<u>ESS1.B: Earth and the Solar System</u>** 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) **PS2.A: Forces and Motion** Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2) **PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4)

Required Lesson Activities (Assessment)
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.
Resources
Tarbuck, Edward J., Frederick K. Lutgens, and Dennis Tasa. *Pearson Earth Science*. Boston, MA: Pearson, 2011. "Model Curriculum: Unit 1B: Planetary Motion." *Model Curriculum: Unit 1B: Planetary Motion*. Web. 15 July 2016. http://www.state.nj.us/education/modelcurriculum/sci/capstoneu1b.shtml Inverse square law for light and Inverse square law - force: Students use the simulators to ask questions and define problems. Students draw conclusions on inverse relationships based on the data from their activity and support their conclusions with evidence from the activity. http://astro.unl.edu/classaction/animations/stellarprops/lightdetector.html http://www.physicsclassroom.com/shwave/gravitn.cfm Orbital Motion Students use the simulation to investigate the nature of an elliptical orbit of a planet or other satellite about the Sun or some central body. http://www.physicsclassroom.com/shwave/orbits.cfm Gravity and Orbits: Students analyze the relationship between the Sun, Earth, Moon and space station, including orbits and positions. Students manipulate variables to show how gravity controls the motion of our solar system. Students make predictions how motion would change if gravity was stronger or weaker. https://phet.colorado.edu/en/simulation/gravity-and-orbits Orbital Motion: Students investigate why planets move in ellipses rather than orbits. http://interactives.ck12.org/simulations/physics/orbital-motion/app/index.html?referrer=ck12Launcher&backUrl=http://interactives.ck12.org/simulations/ Kepler's Laws of Planetary Motion: Students use a simulation to launch a spacecraft to Mars applying Kepler's Laws. http://interactives.ck12.org/simulations/physics/journey-to-mars/app/index.html?referrer=ck12Launcher&backUrl=http://interactives.ck12.org/simulations/ Students use the simulation to investigate the nature of an elliptical orbit of a planet or other satellite about the Sun or some central body. Orbit of the Space Station Mercury's Deviated Orbit

Science and Engineering Practices	Crosscutting Concepts
Using Mathematics and Computational Thinking Use mathematical representations of phenomena to describe explanations. (HS-ESS1-4), (HS-PS2-2; HS-PS2-4) **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Theories and laws provide explanations in science. (HS-PS2-4) Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-4)	**<u>Scale, Proportion, and Quantity</u>** 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) **Systems and System Models** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) **Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) **Connections to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and Technology** Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-4)

Unit Description

Unit Title
Physics of the Earth System
Unit Summary
Students investigate the energy within the Earth as it drives Earth's surface processes. Students evaluate evidence of the past and current movements of continental and oceanic crust for theory of plate tectonics to explain the ages of crustal rocks. Finally, students develop a model based on evidence of the Earth's interior to describe the cycle of matter by thermal convection.
Learning Objectives Based on Mastery Skills
HS-ESS1-5: 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. **HS-ESS2-1:** 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. **HS-ESS2-3:** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. **HS-PS2-5 (*secondary to HS-ESS2-3*)**: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. **HS-PS4-1 (*secondary to HS-ESS2-3*):** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. **HS-PS2-1:** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
Essential Questions
How long does it take to make a mountain? How much force is needed to move a continent? What can possibly provide the energy for that much force? Are all rocks the same age?
Evidence of Learning
Disciplinary Core Ideas **ESS1.C: The History of Planet Earth** 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) **ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts. (HS-ESS2-1) 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) **ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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. (ESS2.B Grade 8 GBE) (secondary to HS-ESS1-5),(HS-ESS2-1)

Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (ESS2.B Grade 8 GBE) (HS-ESS2-1) 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. (HS-ESS2-3) **PS1.C: Nuclear Processes** Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.(secondary to HS-ESS1-5) **PS2.A: Forces and Motion** Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) **PS2.B: Types of Interactions** 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) **PS4.A: Wave Properties** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)
Required Lesson Activities (Assessment)
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. 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. 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.
Resources
Tarbuck, Edward J., Frederick K. Lutgens, and Dennis Tasa. *Pearson Earth Science*. Boston, MA: Pearson, 2011. "Model Curriculum: Unit 2: Physics of the Earth System." *Model Curriculum: Unit 2: Physics of the Earth System*. Web. 15 July 2016. http://www.state.nj.us/education/modelcurriculum/sci/capstoneu2.shtml 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. Le Pichon's 1968 seafloor age data: Students map and analyze LePichon's field data to identify patterns in the ages of the ocean floor.

Extensions: Additional maps and data may be found at NOAA Marine Geology and Geophysics and from their image site. An associated research paper may be found here. Citation for research paper: Muller, R. D., M. Sdrolias, C. Gaina, and W. R. Roest (2008), Age, spreading rates, and spreading asymmetry of the world's ocean crust, Geochem. Geophys. Geosyst., 9, Q04006, doi:10.1029/2007GC001743. IRIS - Measuring the Rate of Plate Motion: Students compare GPS data of plate motion to determine the rate at which tectonic plates move. Alternatively, students use real-time plate motion data from UNAVCO to determine the rate at which plates move. IODP: Deep Earth Academy Core Data investigations: Students investigate seafloor core data to evaluate multiple lines of evidence to support the dynamic plate theory. GeoMapApp and GeoMapApp educational activities: Students visualize and explore various lines of evidence for plate dynamics and evaluate the strengths of each line of evidence in supporting the dynamic plate theory. Lithosphere age research paper: Students read this article which describes how seismic data is used to determine the age of the crust, and the inherent issues associated with the procedure. They use this information in their analysis, evaluation, and synthesis of evidence for the dynamic plate theory. Citation for research paper: Poupinet, G., Shapiro, N.M., Worldwide distribution of ages of the continental lithosphere derived from a global seismic tomographic model, Lithos (2008), doi:10.1016/j.lithos.2008.10.023. Google Earth Age of the Lithosphere: Students compare the age of the seafloor and continental crust using the data at this site, or USGS data found here or found here. Geologic time and rates of landscape evolution: Students model rates of landscape evolution to gain an understanding of change over deep, historical, and recent time. Alternatively, students compare rates of erosion of a mountain landscape to agricultural lands by completing this activity. Hotspot Lesson: Students analyze the rate of movement of the Hawaiian Island chain to further understand rates of change in geologic processes. How Erosion Builds Mountains: by Mark Brandon and Nicholas Pinter, from Scientific American. Students read this article and identify feedbacks in the mountain building process. To support their model, they gather supporting evidence using this Isostasy model. Comparing models of the Earth's interior from data: Students compare two models of the Earth's interior and argue from evidence which model more strongly supports the evidence. Seismic Wave: Students receive additional practice in the interpretation of seismic data to model the interior of the Earth.

Science and Engineering Practices	Crosscutting Concepts
Analyzing and Interpreting Data Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1) **Using Mathematics and Computational Thinking** Use mathematical representations of phenomena to describe explanations. (HS-PS4-1) Planning and Carrying Out Investigations 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) **Developing and Using Models** Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1; HS-ESS2-3) **Engaging in Argument from Evidence** Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5) **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Theories and laws provide explanations in science. (HS-PS2-1) Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1) **Scientific Knowledge is Based on Empirical Evidence** 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) Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3)	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1; HS-PS2-5; HS-PS4-1) **Energy and Matter** Energy drives the cycling of matter within and between systems. (HS-ESS2-3) **Stability and Change** 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) **Patterns** Empirical evidence is needed to identify patterns. (HS-ESS1-5) **Connections to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and Technology** Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS2-3)

Unit Description

Unit Title
Dynamic Earth Systems
Unit Summary
Students plan and carry out investigations, analyze and interpret data, develop and use models, and engage in arguments from evidence are key practices to explore the dynamic nature of Earth systems to illustrate how Earth's interacting systems cause feedback effects on other Earth systems, to investigate the properties of water and its effects on Earth materials and surface processes, and to model the cycling of carbon through all of the Earth's spheres. Students seek evidence to construct arguments about the simultaneous co-evolution of the Earth's systems and life on Earth.
Learning Objectives Based on Mastery Skills
HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **HS-ESS2-5:** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. **HS-ESS2-6:** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. **HS-ESS2-7:** Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

Essential Questions
How do changes in the geosphere affect the atmosphere? How do the properties and movements of water shape Earth's surface and affect its systems? How does carbon cycle among the hydrosphere, atmosphere, geosphere, and biosphere? How do living organisms alter Earth's processes and structures?
Evidence of Learning
Disciplinary Core Ideas **<u>ESS2.A: Earth Materials and Systems</u>** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-2.) **<u>ESS2.C: The Roles of Water in Earth's Surface Processes</u>** The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5) **<u>ESS2.D: Weather and Climate</u>** 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) **<u>ESS2.D: Weather and Climate</u>** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6),(HS-ESS2-7) Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6) **<u>ESS2.E Biogeology</u>** The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7)

Required Lesson Activities (Assessment)
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. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. Develop a model based on evidence to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. Develop a model based on evidence to illustrate the biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere, providing the foundation for living organisms. Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth.
Resources
Tarbuck, Edward J., Frederick K. Lutgens, and Dennis Tasa. *Pearson Earth Science*. Boston, MA: Pearson, 2011. "Model Curriculum: HS Earth and Space/Environmental Science Unit 4." *Model Curriculum: HS Earth and Space/Environmental Science Unit 4*. Web. 15 July 2016. http://www.state.nj.us/education/modelcurriculum/sci/capstoneu3.shtml MY NASA DATA: Students select satellite datasets to answer questions related to system interactions and feedbacks. Finding the Crater: Students "visit" different K-T boundary sites, evaluate the evidence found in the cores at each site, find these sites on a map, and predict where the impact crater is located. Images of Change: Students explore these images of the impacts of climate change over time to develop explanations from evidence of how an impact in one component of the Earth system has effects in other components of the Earth system. Climate Reanalyzer: Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system. USGS Realtime Water data and Climate data: Students create and run an investigation to determine the relationship between streamflow and precipitation data, or another parameter. 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? Earth Systems Activity: Students model the carbon cycle and it's connection with Earth's climate. Carbon and Climate: Students run a model of carbon sources and sinks and interpret results to develop their own model of the relationship of the carbon cycle to the Earth's climate. Students can also work through the content of the entire module called Carbon Connections which includes numerous models and interactives to gain a deeper understanding of the role of carbon in the climate system. 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.

Science and Engineering Practices	Crosscutting Concepts
Analyzing and Interpreting Data Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims	**Stability and Change** 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-ESS2-2)

or determine an optimal design solution. (HS-ESS2-2) **Planning and Carrying Out Investigations** 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-ESS2-5) **Developing and Using Models** Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-6) **Engaging in Argument from Evidence** Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7)	Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7) **Structure and Function** The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5) **Energy and Matter** The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6) **Influence of Engineering, Technology, and Science on Society and the Natural World** 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)

Unit Description

Unit Title
Human Activity & the Climate System
Unit Summary
Students evaluate claims, analyze and interpret data, and develop and use models to explore the core ideas centered on the Earth's climate system. Students evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by the atmosphere and Earth's various surfaces. They apply these core ideas when they use a quantitative model to describe how variations in the flow of energy into an out of the Earth's systems result in changes in climate, and how carbon is cycle through all of the Earth's spheres. They analyze geoscience data to make the claim that one change to Earth's surface can cause changes to other Earth systems, such as the climate system. Finally, students analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
Learning Objectives Based on Mastery Skills
HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. **HS-ESS3-5:** Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. **HS-ESS2-2 (*secondary to HS-ESS2-4*):** Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **HS-ESS1-4 (*secondary to HS-ESS2-4*):** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. **HS-ESS2-6 (*secondary to HS-ESS3-5*):** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. **HS-PS4-4 (*secondary to HS-ESS2-4*):** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
Essential Questions
What happens if we change the chemical composition of our atmosphere? How does carbon cycle among the hydrosphere, atmosphere, geosphere, and biosphere? (repeated from Environmental Science - Earth Unit 4: Dynamic Earth Systems) How do changes in the geosphere affect the atmosphere? (repeated from Environmental Science - Earth Unit 4: Dynamic Earth Systems) What happens to solar energy as it moves through the atmosphere and strikes a surface? What is the current rate of global or regional climate change and what are the associated future impacts to Earth's systems?

Evidence of Learning

Disciplinary Core Ideas

PS4.B: Electromagnetic Radiation

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)

ESS1.B: Earth and the Solar System

Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4)

ESS2.A: Earth Materials and Systems

The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)

Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-2)

ESS2.D: Weather and Climate

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), (HS-ESS2-4)

Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6)

Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4)

ESS3.D: Global Climate Change

Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

ESS1.B: Earth and the Solar System

Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)

Required Lesson Activities (Assessment)

Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Use empirical evidence to differentiate between how variations in the flow of energy into and out of Earth's systems result in climate changes.

Use multiple lines of evidence to support how variations in the flow of energy into and out of Earth's systems result in climate changes.

Develop a model based on evidence to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

Develop a model based on evidence to illustrate the biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere, providing the foundation for living organisms.

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.
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.
Analyze geosciences data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
Quantify and model change and rates of change in geosciences data and rates of global or regional climate change and associated impacts to Earth systems.

Resources

Withgott, Jay. *Environmental Science: Your World, Your Turn*. Hardcover: Pearson, 2011.
"Model Curriculum: Unit 4: Human Activity & the Climate System." *Model Curriculum: Unit 4: Human Activity & the Climate System*. Web. 15 July 2016.
http://www.state.nj.us/education/modelcurriculum/sci/capstoneu4.shtml
Glaciers: Students will explain how environmental conditions (temperature and precipitation) impact glacial mass budget; identify where snow accumulates in a glacier and justify why.
MY NASA DATA: Students gather, display, and interpret incoming and outgoing solar radiation data to develop a model of the interactions of Earth's various surface types and incoming solar radiation.
Solar Variability & Orbital Cycles: Students select scientific readings and datasets and identify relationships among solar variability, orbital cycles, and Earth's climate over various time scales.
Modification of OER: Ice Cores and Orbital variations: Students apply the output of this visualization to develop a model of orbital changes as related to Earth's temperature over deep time.
Climate Reanalyzer: Students use the data on this website to assess diurnal, monthly, seasonal, and annual changes in the weather and climate parameters. Alternatively, data may be acquired from NASA NEO or NASA Giovanni.
Climate Reanalyzer: Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system.
Climate Modeling 101: Students use the information in this tutorial to understand how climate models are created and interpreted. They apply what they learn to the climate model outputs they interpret.
Carbon Cycle Lesson Plan: Students develop and apply basic and/or advanced mathematical modeling skills to climate modeling.
Paleoclimate Data Access: Students select from various paleoclimate datasets. After they understand how the data was collected and how it is interpreted, they display and analyze the data. They interpret the data and seek relationships among the datasets in order to understand changes in the Earth's climate over time.
Carbon Connections Climate Model: Students control the inputs of various climate forcings to observe the outputs on the climate system. Students can also work through the content of the entire module called Carbon Connections which includes numerous models and interactives to gain a deeper understanding of the role of carbon in the climate system.
NASA - Climate Change Impacts and EPA - Climate Change Impacts: Students construct an explanation and cite evidence for how changes in climate have influenced human activity.
Images of Change: Students explore these images of the impacts of climate change over time to develop

explanations from evidence of how an impact in one component of the Earth system has effects in other components of the Earth system.	
Science and Engineering Practices	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information 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) **Developing and Using Models** Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4), (HS-ESS2-6) **Analyzing and Interpreting Data** Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS2-1), (HS-ESS3-5) **Using Mathematical and Computational Thinking** Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4) **Connections to Nature of Science** **Scientific Investigations Use a Variety of Methods** Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5) New technologies advance scientific knowledge. (HS-ESS3-5) **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence. (HS-ESS3-5) Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4),(HS-ESS3-5)	**Cause and Effect** Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4), (HS-ESS2-4) **Scale, Proportion, and Quantity** Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4) **Stability and Change** 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-ESS2-2), (HS-ESS3-5) **Energy and Matter** The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6) **Connections to Engineering, Technology. and Applications of Science** **Influence of Engineering, Technology, and Science on Society and the Natural World** 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) 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)

Unit Description

Unit Title
Human Activity & Sustainability
Unit Summary
Students construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards is connected to human activity. Additionally, while students are exploring this idea they apply scientific and engineering ideas to design, evaluate, and refine a device that can be used to minimize the impacts of natural hazards. They create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity, and create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. They use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity, and evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
Learning Objectives Based on Mastery Skills
HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **HS-ESS3-3:** Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. **HS-ESS3-4:** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. **HS-ESS3-6:** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. **HS-ETS1-3:** 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-LS4-6 (*secondary to*HS-ESS3-4):** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
Essential Questions
How do human activities influence the global ecosystem? How might we change habits if we replaced the word “environment” with the word “life support system”? Is the damage done to the global life support system permanent? How can the impacts of human activities on natural systems be reduced? What are the relationships among earth’s systems and how are those relationships being modified due to human activity?
Evidence of Learning
Disciplinary Core Ideas **ESS3.A: Natural Resources** Resource availability has guided the development of human society. (HS-ESS3-1) **ESS3.B: Natural Hazards** Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1) **LS4.C: Adaptation** Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-6, secondary to HS-ESS3-3)

ESS3.C: Human Impacts on Earth Systems The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3) Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) **ESS3.D: Global Climate Change** Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6) **ESS2.D: Weather and Climate** Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to HS-ESS3-6) **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. (secondary to HS-ESS3-4)
Required Lesson Activities (Assessment)
Identify five threats to ecosystems from human activities. Understand what factors affect climate change and what the current trajectory and implications of climate change are for the next century. Construct an explanation based on valid and reliable evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. Use empirical evidence to differentiate between how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Quantify and model change and rates of change in the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Create or revise a simulation based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations to test a solution to mitigate adverse impacts of human activity on biodiversity. Use empirical evidence to make claims about the impacts of human activity on biodiversity. Break down the criteria for the design of a simulation to test a solution for mitigating adverse impacts of human activity on biodiversity into simpler ones that can be approached systematically based on consideration of trade-offs. Design a solution for a proposed problem related to threatened or endangered species or to genetic variation of organisms for multiple species. Analyze costs and benefits of a solution to mitigate adverse impacts of human activity on biodiversity. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems based on scientific knowledge and student-generated sources of evidence; prioritize criteria and tradeoff considerations. Use a computational representation to illustrate the relationships among Earth systems and how these relationships are being modified due to human activity. Describe the boundaries of Earth systems.

Analyze and describe the inputs and outputs of Earth systems.
Resources
Withgott, Jay. *Environmental Science: Your World, Your Turn*. Hardcover: Pearson, 2011. "Model Curriculum: Unit 5: Human Activity & Sustainability." *Model Curriculum: Unit 5: Human Activity & Sustainability*. Web. 15 July 2016. http://www.state.nj.us/education/modelcurriculum/sci/capstoneu5.shtml Cost-Benefit Analysis Primer: Students read this explanation about how cost-benefit analysis is derived and applied in order to apply this model to design solutions related to human sustainability. Students then read the application of CBA to water sanitation. Carbon Stabilization Wedge: Students play this game in order to evaluate competing design solutions for developing, managing, and utilizing energy resources based on cost-benefit ratios. One For All: A Natural Resources Game: Identify a strategy that would produce a sustainable use of resources in a simulation game. Draw parallels between the chips used in the game and renewable resources upon which people depend. Draw parallels between the actions of participants in the game and the actions of people or governments in real-world situations. Building Biodiversity and the PREDICTS project and GLOBIO project: Students explore this website to develop an understanding of how computational models of the impacts on biodiversity are created. Next, they explore Conservation Maps for a global perspective of land use and conservation efforts. Schoolyard Biodiversity: Students assess the biodiversity in their schoolyards, and apply their model outputs to predict the changes in biodiversity as related to human impacts and the application of sustainable practices. I=P*A*T Equation and Its Variants: Students read this article to learn how ecological economics models are developed and applied to further understand human impacts on our environment. National Climate Assessment: Students explore the simulations found at this website in order to create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Stormwater Calculator or the Water Erosion Prediction Project: Students apply the storm water runoff calculator to determine the impacts of land use change, precipitation variations, and other parameters on runoff. The Bean Game: Exploring Human Interactions with Natural Resources: This activity explores the various influences of human consumption of natural resources over time. (Use this as a primer for making a computational model). NSA Challenge: Recycling for a Cleaner World: Students will develop a strategy to increase recycling and waste diversion for their school. Land and People: Finding a Balance: This environmental study project allows a group of students to consider real environmental dilemmas concerning water use and provide solutions to these dilemmas. Reefs at Risk: and NOAA Coral Reefs at Risk: Students access and explore a series of interactive maps displaying coral reef data from around the globe and develop hypotheses related to the impacts of climate change (i.e. increased levels of carbon dioxide in our atmosphere) on coral reef health. GLOBE Carbon Cycle: Students collect data about their school field site through existing GLOBE protocols of phenology, land cover and soils as well as through new protocols focused on biomass and carbon stocks in vegetation. Students participate in classroom activities to understand carbon cycling at local and global scales. Students expand their scientific thinking through the use of systems models. Earth: Planet of Altered States: Watch a segment of a NASA video and discuss how the earth is constantly changing.

Science and Engineering Practices	Crosscutting Concepts
Constructing Explanations and Designing Solutions	**Cause and Effect** Empirical evidence is required to differentiate

Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS3-1) Design 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-ESS3-4) **<u>Using Mathematics and Computational Thinking</u>** Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-ESS3-3) Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6) Create or revise a simulation of a phenomenon, designed device, process, or system. (HS-LS4-6)	between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1), (HS-LS4-6) **<u>Systems and System Models</u>** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-6) **<u>Stability and Change</u>** Feedback (negative or positive) can stabilize or destabilize a system. (HSESS3-4), (HS-LS4-6) 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-ESS3-3) **Connections to Engineering, Technology, and Applications of Science** **<u>Influence of Science, Engineering, and Technology on Society and the Natural World</u>** Modern civilization depends on major technological systems. (HS-ESS3-3) Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-4) New technologies can have deep impacts on society and the environment, including some that were not anticipated. (HS-ESS3-3) **Connections to Nature of Science** **Science is a Human Endeavor** Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3)

Unit Description

Unit Title
Human Activity & Energy
Unit Summary
Students engage in argument from evidence, develop and use models, ask questions and define problems, construct explanations and design solutions, and evaluate information. This unit focuses on the physics core ideas surrounding energy and energy transformations as related to the Earth System core idea of energy needs for human activity. Students 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. They apply engineering design principles to design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. Within this unit students also apply the core ideas of related to the behavior of electromagnetic energy 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. They 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 (secondary concept). They apply these core ideas to 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. At the basis of our energy needs is the need for resources to create energy, and therefore students evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
Learning Objectives Based on Mastery Skills
HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. **HS-ETS1-1:** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. **HS-ETS1-4:** 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-PS3-1:** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-2:** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). **HS-PS3-3:** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. **HS-PS3-5 (*secondary to HS-PS3-3*):** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. **HS-PS4-3:** Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. **HS-PS4-5:** 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.

Essential Questions
What is the best energy source for a home? How would I meet the energy needs of a house of the future? How can we use mathematics in decision-making about energy resources? What is energy? How can we design a low technology system that would insure the availability of energy to residents if catastrophic damage to the grid occurred? How can electromagnetic radiation be both a wave and a particle at the same time? How does the International Space Station power all of its equipment? How do astronauts communicate with people on the ground?
Evidence of Learning
Disciplinary Core Ideas **<u>ESS3.A: Natural Resources</u>** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2) **PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-2) At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2) **PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) 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) **PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3) <u>PS3.C: Relationship between Energy and Forces</u> When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5, secondary to HS-PS3-3) **PS4.A: Wave Properties** 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) **PS4.B: Electromagnetic Radiation** Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) 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)
Required Lesson Activities (Assessment)
Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost benefit ratios, scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, and ethical considerations). Use models to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, and ethical considerations). 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. 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. 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. 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.
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.

Resources

Withgott, Jay. *Environmental Science: Your World, Your Turn*. Hardcover: Pearson, 2011.
"Model Curriculum: Unit 6: Human Activity & Energy." *Model Curriculum: Unit 6: Human Activity & Energy*. Web. 15 July 2016.
http://www.state.nj.us/education/modelcurriculum/sci/capstoneu6.shtml
Carbon Stabilization Wedge: Students play this game in order to evaluate competing design solutions for developing, managing, and utilizing energy resources based on cost-benefit ratios.
One For All: A Natural Resources Game: Identify a strategy that would produce a sustainable use of resources in a simulation game. Draw parallels between the chips used in the game and renewable resources upon which people depend. Draw parallels between the actions of participants in the game and the actions of people or governments in real-world situations.
National Climate Assessment: Students explore the simulations found at this website in order to create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
Know Your Energy Costs: The goal of this activity is to become aware of how much energy you use at school — and the financial and environmental costs.
Earth: Planet of Altered States: Watch a segment of a NASA video and discuss how the earth is constantly changing.
Climate Reanalyzer: Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system.
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.
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. 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-interferencePHeT 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.

Science and Engineering Practices	Crosscutting Concepts
Asking Questions and Defining Problems Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2) **Developing and Using Models** 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) **Using Mathematics and Computational Thinking** Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) **Constructing Explanations and Designing Solutions** 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) **Engaging in Argument from Evidence** Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3) Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical	**Cause and Effect** Systems can be designed to cause a desired effect. (HS-PS4-5) 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) **Systems and System Models** Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-1) 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) **Energy and Matter** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3) Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2) **Connections to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and**

arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2) **Obtaining, Evaluating, and Communicating Information** 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) **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. (secondary to HS-ESS3-2) **Connections to Nature of Science** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1) **Science is a Human Endeavor** Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3) **Science Addresses Questions About the Natural and Material World** Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2) Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2) Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2)	**Technology** Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5) **Influence of Science, Engineering and Technology on Society and the Natural World** 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), (HS-PS4-5) Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-2) Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2) **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)