Unit 6 Electricity and Magnetism

Content Area: **Science**
Course(s):
Time Period: **February**
Length: **10 Blocks**
Status: **Published**

Topic Outline

Electrostatics

- Introduction to Charge and Coulomb's Law, Electric Fields

Electricity

- Current, Voltage, Resistance, and DC circuits

Magnetism

- Introduction to Magnets, Magnetic Field

Electric and Magnetic Fields

- Changing electric fields cause changing magnetic fields and vice versa

Unit Summary

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

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

updated from 11.19.15

Enduring Understandings

- An electric current can produce a magnetic field and a changing magnetic field can produce an electric current.

- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Essential Questions

- How can one explain and predict the interactions between objects and within a system of objects?
- What are the relationships between electric currents and magnetic fields?
- How can a force be exerted on an object when nothing is touching it?

Student Learning Objectives (PE, SEP, DCI, CCC) & Aligned Standards

- Students will solve basic series and parallel circuits.
- Students will discuss applications of magnetic and electric fields.

Performance Expectations

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

Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. *[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]* **(HS-PS3-5)**

Science and Engineering Practices

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 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)

Disciplinary Core Ideas

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)

PS3.C: Relationship between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5)

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-5)

- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS3-5)

SCI.9-12.1.2	Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments.
SCI.9-12.1.3	Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
SCI.9-12.1.4	Mathematical representations are needed to identify some patterns.
SCI.9-12.1.5	Empirical evidence is needed to identify patterns.
SCI.9-12.2.2	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.
SCI.9-12.2.3	Systems can be designed to cause a desired effect.
SCI.9-12.2.4	Changes in systems may have various causes that may not have equal effects.

SCI.9-12.3.2	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
SCI.9-12.3.3	Patterns observable at one scale may not be observable or exist at other scales.
SCI.9-12.3.4	Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
SCI.9-12.3.5	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).
SCI.9-12.4.2	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.
SCI.9-12.4.4	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.
SCI.9-12.5.4	Energy drives the cycling of matter within and between systems.
SCI.9-12.6.2	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.
SCI.9-12.7.2	Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
SCI.9-12.7.3	Feedback (negative or positive) can stabilize or destabilize a system.
SCI.9-12.7.4	Systems can be designed for greater or lesser stability.
SCI.9-12.CCC.1.1	students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.
SCI.9-12.CCC.2.1	students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.
SCI.9-12.CCC.3.1	students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).
SCI.9-12.CCC.5.1	students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
SCI.9-12.CCC.6.1	students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system’s function and/or solve a problem. They infer the functions and properties of natural and

	designed objects and systems from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.
SCI.9-12.CCC.7.1	students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.
SCI.HS-PS3-5	Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
SCI.HS-PS2-4	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
SCI.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.
SCI.HS-PS2-5	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.
SCI.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 position of particles (objects).
SCI.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.

Concepts & Formative Assessment

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

Concepts

- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space.
- Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Formative Assessment

Students who understand the concepts are able to:

- Plan and conduct an investigation individually and collaboratively to produce data that can serve as the basis for evidence that an electric current can produce a magnetic field.
- Plan and conduct an investigation individually and collaboratively to produce data that can serve as the basis for evidence that a changing magnetic field can produce an electric current.
- In experimental design, decide on the types, amounts, and accuracy of data needed to produce reliable measurements, consider limitations on the precision of the data, and refine the design accordingly.
- Collect empirical evidence to support the claim that an electric current can produce a magnetic field.

- Collect empirical evidence to support the claim that a changing magnetic field can produce an electric current.

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

Concepts

- When two objects interacting through a field change relative position, the energy stored in the field is changed.
- Cause-and-effect relationships between electrical and magnetic fields can be predicted through an understanding of inter- and intra-molecular forces (protons and electrons).

Formative Assessment

Students who understand the concepts are able to:

- Develop and use an evidence-based model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
- Suggest and predict cause-and-effect relationships for two objects interacting through electric or magnetic fields.

Resources

Magnet and Compass (uses Java) Phet simulation

- Predict the direction of the magnet field for different locations around a bar magnet
- Relate magnetic field strength to distance quantitatively and qualitatively
- Describe how the earth's magnet field relates to a bar magnet

Magnets and Electromagnets (uses Java) Phet simulation

- Predict the direction of the magnet field for different locations around a bar magnet and electromagnet
- Compare and contrast bar magnets and electromagnets
- Identify the characteristics of electromagnets that are variable and what effects each variable has on the magnetic field's strength and direction
- Relate magnetic field strength to distance quantitatively and qualitatively

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

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

Faraday's Law: Investigate Faraday's law and how a changing magnetic flux can produce a flow of electricity!

Internet Resources:

- http://www.wcsscience.com/magnet/madness.html
- http://www.exploratorium.edu/snacks/iconmagnetism.html

Assessments

- Students can map the magnetic field around a bar magnet with a compass or iron filings. Students should observe how distance from the magnet affects the field lines. They should also observe the directionality of the field lines.
- Students can deflect a compass needle with a current carrying wire. Students might analyze how distance, current strength, and current direction affect the compass needle.
- Students can put a bar magnet through a solenoid and measure the current through the wire. Students can also experiment with the number of loops, the radius of the coil, the gauge of wire, or the length of the coil.
- Students can design and build a motor or generator. They might also observe a premade toy motor.
- Students can create a basic electromagnet by wrapping an iron nail in coiled wire and connecting the ends of the wire to a battery. Students could explore how changing the number of coils, length of the nail, polarity of the nail, or thickness of the nail affects the magnetic field. This will allow students to see how a magnetic field can be measured by how many washers/paper clips the electromagnet can pick up.
- Students can build a basic battery with lemon juice, pennies, sand paper, and construction paper and use it to power an LED bulb. Students should understand that "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.
- Students should investigate and construct a simple maglev train and explore what variables (mass, magnetic field strength, etc.) affect the speed and running efficiency of the train.
- Using field-mapping kits with silver oxide pens and conductive gridded paper, students could map electromagnetic fields and examine any change in electrical potential energy.

The Science Classroom

Students will build on their previous experiences with Coulomb's law and Newton's laws regarding forces as they develop an understanding of relationships between electric and magnetic fields, and how objects interact with each other and with electric and magnetic fields. Students have an understanding of how gravitational forces at a distance are explained by fields, and they have previously looked at energy transfer through space.

In order to build an understanding of forces at a distance and the transfer of energy through space, students should examine the relationships between flowing current and magnetic fields. Students should know that forces at a distance are explained by fields (gravitational, electric, and magnetic). These fields permeate space and can transfer energy through space.

Students should plan and carry out investigations to explore the relationships between electrical currents and magnetic fields. In their experimental design, students should decide on the types, amount, and accuracy of the data needed to produce reliable measurements, and they should consider limitations on the precision of the data and refine the design accordingly. Examples of investigations students might plan and carry out include:

- Students can map the magnetic field around a bar magnet with a compass or iron filings. Students should observe how distance from the magnet affects the field lines. They should also observe the directionality of the field lines.
- Students can deflect a compass needle with a current carrying wire. Students might analyze how distance, current strength, and current direction affect the compass needle.
- Students can put a bar magnet through a solenoid and measuring the current in the wire. Students could also experiment with the number of loops, radius of the coil, gauge of wire, or length of the coil.
- Students can design and build a motor or generator. They might also observe a premade toy motor.

- Students can create a basic electromagnet by wrapping an iron nail in coiled wire and connecting the ends of the wire to a battery. Students could explore how changing the number of coils, length of the nail, polarity of the nail, or thickness of the nail affects the magnetic field. This will allow students to see how a magnetic field can be measured by how many washers/paperclips the electromagnet can pick up.
- *Students can build a basic battery with lemon juice, pennies, sand paper, and construction paper and use it to power an LED bulb. Students should understand that "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.*
- Students should investigate and construct a simple mag-lev train and explore what variables (mass, magnetic field strength, etc.) affect the speed and running efficiency of the train.
- Using field-mapping kits with silver oxide pens and conductive gridded paper, students could map electromagnetic fields and examine any change in electrical potential energy.

Experimental evidence should allow students to support claims about how an electric current can produce a magnetic field, and how a changing magnetic field can produce an electric current. Claims should be supported and modeled mathematically when appropriate. Students should choose and interpret units consistently and organize and analyze data in graphs.

Students might also conduct short or more sustained research projects around the concepts of electric current and magnetic fields. They should collect relevant data from a broad spectrum of sources, examine adequate evidence, and construct rigorous explanations for how electric currents produce magnetic fields and how changing magnetic fields can produce electric currents.

Students should be able to develop descriptive (and in some cases quantitative) models, based on the evidence from their investigations 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. This could include using Coulomb's law from Unit 2 to mathematically explain some observed phenomena. Students should have an understanding of what happens when two charges of opposite polarity are near each other. Students should be able to predict cause-and-effect relationships for two objects interacting through electric or magnetic fields. Student models might be mathematical models, drawings, diagrams, or text.

Students should examine relevant text about objects interacting through electric or magnetic fields, draw evidence, assess strengths and limitations of sources, and integrate information into written explanations (models). Students might use digital media in presentations of their models to enhance understanding. This might include textual, graphical, audio, visual, and interactive elements.

Depending on the sequence of courses, students may or may not have an understanding of the structure of the atom. This concept is covered in the chemistry course. Appropriate descriptions about electricity and the flow of electrons should be provided based on students' level of understanding. Teachers might draw an analogy between thermal conductivity and electrical conductivity.

It is important to note that this unit does not require the teaching of simple electrical circuits, Ohm's law, the right-hand rule, or Maxwell's equations. For enrichment, the instructor might, at his or her discretion, introduce these concepts through the analogy of water flowing through a pipe. This unit does not address dipoles, directionality of magnetic fields, and the causes for magnetism in certain substances. The unit focuses on a conceptual overview of electricity and magnetism.

Connecting with English Language Arts Literacy and Mathematics

English Language Arts/Literacy

- Conduct short as well as more sustained research projects to support the claim that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- Collect relevant data from a broad spectrum of sources about the claim that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current, and assess the strengths and limitations of each source.

- Collect and examine adequate empirical evidence to construct a rigorous explanation for the claim that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- Conduct short as well as more sustained research projects to determine the forces between objects and the changes in energy of the objects as they interact through electric or magnetic fields; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the interaction of two objects through electric or magnetic fields, demonstrating understanding of the interaction of two objects through electric or magnetic fields.
- Gather relevant information on the interaction of two objects through electric or magnetic fields from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the development of a model to illustrate the forces between objects and the changes in energy of the objects as they interact through electric or magnetic fields; integrate information into text describing the interaction of two objects through electric or magnetic fields selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- Draw evidence from informational texts to support analysis, reflection, and research about two objects interacting through electric or magnetic fields and the forces between objects and the changes in energy of the objects due to the interaction.
- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to model two objects interacting through electric or magnetic fields, and illustrate the forces between objects and the changes in energy of the objects due to the interaction to enhance understanding of findings, reasoning, and evidence and to add interest.

Mathematics-

- Use units as a way to understand the claim that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current; choose and interpret units consistently in formulas representing the production of a magnetic field from an electric current and the production of an electric current from a changing magnetic field; choose and interpret the scale and origin in graphs and data displays representing magnetic fields and electric currents.
- Define appropriate quantities for the purpose of descriptive modeling of the production of a magnetic field from an electric current and the production of an electric current from a changing magnetic field.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the production of a magnetic field from an electric current and the production of an electric current from a changing magnetic field.
- Represent symbolically two objects interacting through electric or magnetic fields, the forces between objects, the changes in energy of the objects due to the interaction, and manipulate the representing symbols. Make sense of quantities and relationships between two objects interacting through electric or magnetic fields, the forces between objects, the changes in energy of the objects due to the interaction.
- Use a mathematical 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. Identify important quantities representing two objects interacting through electric or magnetic fields, the forces between objects, and the changes in energy of the objects due to the interaction, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.

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

Research on Student Learning

Before instruction, many students are not aware of the bipolarity of batteries and light bulbs; do not recognize the need for a complete circuit to make a bulb light; and do not succeed in making a lamp light when given a battery and a number of connecting wires. This suggests that they also do not understand or cannot apply the concept of a complete circuit. Teaching sequences that take account of students' ideas can help students make progress in this area. Students have difficulty reasoning that all parts of a circuit are interrelated and influence each other. Instead, they think of circuits in terms of electric current traveling around the circuit meeting each component in turn. They think of a change in the circuit affecting only those components that come after the change. This "sequential" reasoning underlies many problems that students have in understanding electric circuits and is highly resistant to change.

Students tend to start instruction with one concept for electricity in electric circuits which has the properties of movement, storability, and consumability and which students label "current," "energy," or "electricity." Even after instruction, many students do not differentiate between electric current and electric energy. They also tend to think that the battery is the source of the current and that the circuit is initially empty of the stuff that flows through the wires. Many students after instruction believe that a battery releases the same amount of current regardless of the circuit to which it is attached, that the fixed current flows out of the battery and diminishes every time it goes through a circuit element that uses up the current, so that there is less current at the end of the circuit. These beliefs are highly resistant to change. Identifying energy as the quantity that is dissipated can help students reconcile their intuitive belief that something is used up in circuits with the formal knowledge that electric current is conserved.

Little is known about students' reasoning about the microscopic mechanisms that underlie electric current and their interpretation in terms of electrostatic entities. After instruction, high-school students may not be inclined to or, when prompted, may have difficulties relating macroscopic parameters (such as electric current) to microscopic processes and electrostatic interactions (such as forces on charged electrons). Students may think of the battery as the only source of electrons which move in the circuit, i.e., the battery releases electrons into the wires which play no active role; They may also think of electrons moving through a circuit as single unconnected particles moving around.

Students may think of gravity and magnetism interchangeably. They may refer to magnetism as a "type of gravity," but they may also explain gravity in terms of the earth acting like a magnet on objects. Students may think that magnets do not work in a place where there is no air, just like they think about gravity. Students of all ages may also confuse electrostatic and magnetic effects. For example, they may predict that north magnetic poles repel positively charged objects.

Students do not readily recognize the magnetic effect of an electric current. Some think of the wire, rather than the electric current as being the cause of the magnetic effect. Students may think that insulation around the wire prevents the existence of magnetic forces when current flows (NSDL, 2015).

Prior Learning

Physical science

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space, and they can be mapped by their effect on a test object (a charged object or a ball, respectively).
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Earth and space science

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.
- The solar system appears to have formed from a disk of dust and gas drawn together by gravity.

Connections to Other Courses

Physical science

- 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.
- 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.
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- 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.
- 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.
- 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.
- Photoelectric materials emit electrons when they absorb light of a high enough frequency.

Earth and space science

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface

and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output, 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
- Resource availability has guided the development of human society.
- 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.

References

Adapted from the New Jesery NGSS Science Model Curriclum

Connections to NJSLS

English Language Arts

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-5),(HS-PS3-5)
WHST.9-12.7

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5),(HS-PS3-5)
WHST.11-12.8

Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-5), (HS-PS3-5)
WHST.9-12.9

Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-5)

SL.11-12.5

Mathematics

Reason abstractly and quantitatively. (HS-PS3-5) **MP.2**

Model with mathematics. (HS-PS3-5**MP.4**)

Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-5) **HSN.Q.A.1**

Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-5) **HSN.Q.A.2**

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-5) **HSN.Q.A.3**