

Unit Summary
<i>Energy and Motion</i> “Energy” is a real thing--not just some vague term--almost like a power or substance that causes objects to move, speed up, or slow down. This power or substance can be transferred between objects when they collide. Thinking about the world in terms of energy helps us to make sense of how and why things speed up and slow down. This unit is based on 4-PS3-1, 4-PS3-2, 4-PS3-3, 4-PS3-4, 4-ESS3-1, 3-5-ETS1-1, 3-5-ETS1-2, and 3-5-ETS1-3.
Student Learning Objectives
Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. <i>[Assessment Boundary: Assessment does not include quantitative measurements of energy.]</i> (4-PS3-2)
Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. <i>[Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]</i> (4-ESS3-1)
Use evidence to construct an explanation relating the speed of an object to the energy of that object. <i>[Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]</i> (4-PS3-1)
Ask questions and predict outcomes about the changes in energy that occur when objects collide. <i>[Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.]</i> <i>[Assessment Boundary: Assessment does not include quantitative measurements of energy.]</i> (4-PS3-3)
Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.* <i>[Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.]</i> <i>[Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.]</i> (4-PS3-4)
Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)
Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. (3-5-ETS1-2)
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. (3-5-ETS1-3)

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Unit Sequence	
Part A: How does energy move?	
Concepts	Formative Assessment
- Energy can be transferred in various ways and between objects. - Energy can be moved from place to place through sound, light, or electric currents. - Energy is present whenever there are moving objects, sound, light, or heat. - Light also transfers energy from place to place. - Energy can also be transferred from place to place by electric currents; the currents may have been produced to begin with by transforming the energy of motion into electrical energy.	<i>Students who understand the concepts are able to:</i> - Make observations to produce data that can serve as the basis for evidence for an explanation of a phenomenon or for a test of a design solution. - Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

Unit Sequence	
Part B: From what natural resources are energy and fuels derived? In what ways does the human use of natural resources affect the environment?	
Concepts	Formative Assessment
- Cause-and-effect relationships are routinely identified and used to explain change. - Knowledge of relevant scientific concepts and research findings is important in engineering. - Over time, people's needs and wants change, as do their demands for new and improved technologies.	<i>Students who understand the concepts are able to:</i> - Identify cause-and-effect relationships in order to explain change. - Obtain and combine information from books and other reliable media to explain phenomena.

• Energy and fuels that humans use are derived from natural sources. • The use of energy and fuels from natural sources affects the environment in multiple ways. • Some resources are renewable over time, and others are not.	• Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. ✓ Examples of renewable energy resources could include: ○ Wind energy, ○ Water behind dams, and ○ Sunlight. ✓ Examples of nonrenewable energy resources are: ○ Fossil fuels, ○ Fissile materials ✓ Examples of environmental effects could include: ○ Loss of habitat due to dams ○ Loss of habitat due to surface mining ○ Air pollution from burning of fossil fuels.
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Unit Sequence	
Part A: What is the relationship between the speed of an object and its energy?	
Concepts	Formative Assessment
• Energy can be transferred in various ways and between objects. • The faster a given object is moving, the more energy it possesses.	<i>Students who understand the concepts are able to:</i> • Describe various ways that energy can be transferred between objects. • Use evidence (e.g., measurements, observations, patterns) to construct an explanation. • Use evidence to construct an explanation relating the speed of an object to the energy of that object. <i>(Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.)</i>

Part B: In what ways does energy change when objects collide?
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Concepts	Formative Assessment
- Energy can be transferred in various ways and between objects. - Energy can be moved from place to place by moving objects or through sound, light, or electric currents. - Energy is present whenever there are moving objects, sound, light, or heat. - When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. - When objects collide, the contact forces transfer energy so as to change the objects' motions.	<i>Students who understand the concepts are able to:</i> - Describe the various ways that energy can be transferred between objects. - Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. - Ask questions and predict outcomes about the changes in energy that occur when objects collide. Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact. <i>(Assessment does not include quantitative measurements of energy.)</i>

Part A: How can scientific ideas be applied to design, test, and refine a device that converts energy from one form to another?	
Concepts	Formative Assessment
- Science affects everyday life. - Most scientists and engineers work in teams. - Engineers improve existing technologies or develop new ones. - People's needs and wants change over time, as do their demands for new and improved technologies. - Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. - Energy can be transferred in various ways and between objects. - Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. - The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. - Possible solutions to a problem are limited by available materials and resources (constraints).	<i>Students who understand the concepts are able to:</i> - Describe the various ways that energy can be transferred between objects. - Apply scientific ideas to solve design problems. - Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. (Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.) - Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound or passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device. - Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. - Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

• The success of a designed solution is determined by considering the desired features of a solution (criteria). • Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. • Research on a problem should be carried out before beginning to design a solution. • Testing a solution involves investigating how well it performs under a range of likely conditions. • At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	• Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. • Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. • Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
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What It Looks Like in the Classroom

Students conduct investigations to observe that energy can be transferred from place to place by sound, light, heat, and electrical currents. They describe that energy and fuels are derived from natural resources and that their uses affect the environment. Throughout this unit, students obtain, evaluate, and communicate information as they examine cause-and-effect relationships between energy and matter.

To begin the unit of study's progression of learning, students need opportunities to observe the transfer of heat energy. They can conduct simple investigations, using thermometers to measure changes in temperature as heat energy is transferred from a warmer object to a colder one. For example, hot water can be poured into a large Styrofoam cup, and then a smaller plastic cup of cold water can be placed inside the larger cup of water. A thermometer can be placed in each cup, and students can observe and record changes in the temperature of the water in each cup every minute over the course of about 10–15 minutes, or until the temperatures are the same. Students can use their data as evidence to explain that some of the heat energy from the hot water transferred to the cold water. This transfer of heat caused the cold water to become gradually warmer and the hot water to cool. This process continued until the cups of water reached the same temperature.

Students can also place a thermometer in the palm of their hands, close their hands around it, and measure the temperature. They can then place a piece or two of ice into their palms and close their fists around the ice until it melts. When they again measure the temperature of their palms, they will observe a change. Students can use these data to describe how some of the heat from their hands transferred to the ice, causing it to melt, while the ice also decreased the temperature of their

hand. It is important that students understand that heat is transferred from warmer to colder objects. When an object cools, it loses heat energy. When an object gets warmer, it gains heat energy.

To continue learning about energy transfer, students can build simple electric circuits. As students work in small groups to build circuits, they should add a bulb and/or a buzzer to the circuit in order to observe and describe the ways in which energy is transferred in the circuit. (The word “transfer” can refer to a change in the type of energy or a change in the location of energy.) For example, stored energy in a battery is transferred into electrical energy, which is then transferred into light energy if a bulb is added to the circuit. The energy transfers from the battery to the wire and then to the bulb. The same holds true if a buzzer is added to the circuit. The stored energy in the battery is transferred into electrical energy, which is then transferred into sound energy. (Keep in mind that energy is not actually produced. When we say that energy is “produced,” this typically refers to the conversion of stored energy into a desired form for practical use. Students should be encouraged to use the term “transferred” rather than “produced”).

After conducting these types of investigations, the class can create a list of events in which energy is transferred. For example, when a ball is thrown against a wall, some of the motion energy is transferred to sound energy; when water boils on the stove top, heat energy from the stove is transferred to the pot and to the water in the pot; and when a doorbell is rung, electrical energy is transferred into sound energy.

Next, students learn about fuels and energy, and conduct research using books and other reliable media to determine which natural resources are sources of energy. Light, heat, sound, and electricity are all forms of energy. Energy is not matter. Fuels, however, are matter. For example, fossil fuels, such as coal, oil, and natural gas, are matter. When fossil fuels are burned, energy stored in the fuel can be transferred from stored energy to heat, light, electrical, and/or motion energy. Therefore, fuels are considered to be a source of energy.

Energy can also be obtained from other sources, such as wind, water, and sunlight. Air and water are both matter, but when they are moving, they have motion energy. Energy from wind (moving air) and from moving water can be transferred into electrical energy. Light energy from the sun can also be transferred to heat energy or electrical energy. In addition, energy can be released through nuclear fission using materials known as fissile materials.

As students learn about fuels and other sources of energy, they should determine which sources are renewable and which are nonrenewable. Generally, a fuel or source of energy is considered nonrenewable if that source is limited in supply and cannot be replenished by natural means within a reasonable amount of time. Renewable sources of energy are those that are replenished constantly by natural means. Using this general description, all fossil fuels are considered nonrenewable, because these resources were naturally created over millions of years. Fissile materials are also nonrenewable. On the other hand, wind, moving water, and sunlight are renewable sources of energy.

As the population continues to grow, so does the demand for energy. Human use of natural resources for energy, however, has multiple effects on the environment. Students should conduct further research to determine how the use of renewable and nonrenewable resources affects the environment. Some examples include:

- ✓ Changes in and loss of natural habitat due to the building of dams and the change in the flow of water;
- ✓ Changes in and loss of natural habitat due to surface mining; and
- ✓ Air pollution caused by the burning of fossil fuels in factories, cars, and homes.

As students conduct research and gather information from a variety of reliable resources, they can take notes and use the information to describe and explain the impact that human use of natural resources has on the environment.

In order to understand and explain the relationship between an object’s speed and its energy, students need multiple opportunities to observe objects in motion. Students can roll balls down ramps, build and race rubber band cars, or build roller coasters. As they observe the motion of objects, they should collect data about the

relative speed of objects in relation to the strength of the force applied to them. For example, when a ball is placed at the top of a ramp, it has stored energy, due to the force of gravity acting on it. When the ball is released, that stored energy is changed (transferred) into motion energy. Increasing the height of a ramp also increases the amount of stored energy in the ball at the top of the ramp. If the ball is released from a higher starting point, it rolls faster and farther. Likewise, winding the rubber band in a rubber band car stores energy in the rubber band, which is then changed, or transferred, into motion energy (kinetic) as the car moves forward. The more times you wind the rubber band, the greater the amount of stored energy in the rubber band, and the farther and faster the car goes. As students investigate these types of force and motion systems, they should conduct multiple trials, increasing and decreasing the amount of energy, then collect qualitative data as they observe the impact differing amounts of energy have on the relative speed of the object in motion. Students should then use their data as evidence to support their explanation of the relationship between the relative speed of an object and its energy.

Once students understand that the faster an object moves, the more energy it possesses, they can begin to explore ways in which energy can be transferred. As they investigated the relationship between speed and energy, students learned that stored energy was changed, or transferred, into motion energy. To broaden their understanding of energy transfer, students should be provided with opportunities to observe objects colliding and should be encouraged to ask questions that lead to further investigation. For example, if students roll a ball towards a wall, or roll two balls so that they collide, they may observe any or all of the following:

- ✓ Change(s) in the direction of motion
- ✓ Change(s) in speed
- ✓ Change(s) in the type of energy (e.g., motion energy to sound energy, sound energy to heat energy)
- ✓ Change(s) in the type of motion (rolling to bouncing).

As students continue to investigate interactions between moving objects, they should notice that when a moving object collides with a stationary object, some of the motion energy of one is transferred to the other. In addition, some of the motion energy is changed, or transferred to the surrounding air, and as a result, the air gets heated and sound is produced. Likewise, when two moving objects collide, they transfer motion energy to one another and to the surrounding environment as sound and heat. It is important that as students observe these types of interactions, they collect observational data, document the types of changes they observe, look for patterns of change in both the motion of objects and in the types of energy transfers that occur, and make predictions about the future motion of objects. Their investigations will help them understand that:

- ✓ Energy can be transferred in various ways and between objects.
- ✓ Energy is present whenever there are moving objects.
- ✓ Energy can be moved, or transferred, from place to place by moving objects.
- ✓ When objects collide, some energy may be changed or transferred into other types of energy.

In this unit, students will apply scientific ideas about force, motion, and energy in order to design, test, and refine a device that converts energy from one form to another. Through this process, students will learn that science affects everyday life and that engineers often work in teams, using scientific ideas, in order to meet people's needs for new or improved technologies.

To begin the **engineering design process**, students must be presented with the problem of designing a device that converts energy from one form to another. This process should include the following steps:

- ✓ As a class, students should create a list of all the concepts that they have learned about force, motion, and energy.
 - The faster a given object is moving, the more energy it possesses.
 - Energy is present whenever there are moving objects, sound, light, or heat.
 - Energy can be transferred in various ways and between objects.
 - Energy can be moved from place to place by moving objects or through sound, light, or electric currents.
 - When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
 - When objects collide, the contact forces transfer energy so as to change the objects' motions.
- ✓ Have students brainstorm examples of simple devices that convert energy from one form to another. As students give examples, the teacher should draw one or two and have students describe how each device converts energy from one form to another.
- ✓ Next, the teacher can present a "Design Challenge" to students: Design and build a simple device that converts energy from one form to another. Please note that teachers should limit the devices to those that convert motion energy to electric energy or that use stored energy to cause motion or produce light or sound.
- ✓ Small groups of students should conduct research, using several sources of information, to build understanding of "stored energy." Students can look for examples of objects that have stored energy. Stretched rubber bands, compressed springs, wound or twisted rubber bands, batteries, wind-up toys, and objects at the top of a ramp or held at a height above the ground all have stored energy.
- ✓ As a class, determine criteria and possible constraints on the design solutions. For example, devices are only required to perform a single energy conversion (i.e., transfer energy from one form to another), and devices must transfer stored energy to motion, light, or sound. Constraints could include the use of materials readily available in the classroom or provided by the teacher. (An assortment of materials can be provided, including batteries, wires, bulbs, buzzers, springs, string, tape, cardboard, balls, rubber tubing, suction cups, rubber bands of various sizes, construction paper, craft sticks, wooden dowels or skewers, buttons, spools, glue, brads, paper clips, plastic cups, paper plates, plastic spoons, straws, Styrofoam, and cloth.) A time constraint could also be set, if desired. All criteria and constraints should be posted on chart paper so that groups can refer to them as needed.
- ✓ Students should work in small, collaborative groups to design and build their device. Examples of possible devices could include:

- A simple rubber band car that converts the stored energy in a twisted rubber band into motion energy.
 - A simple roller coaster that converts the stored energy in a marble held at the top of the roller coaster into motion energy.
 - A whirly bird that converts stored energy (in a student's muscles) into motion energy.
 - A ball launcher that converts stored energy in a compressed spring, compressed suction cup, or stretched rubber band into motion energy when the ball is launched.
- ✓ Students should create a poster that includes a diagram of the device and a description of how the device transfers energy from one form to another. Every group should have the opportunity to present their device and explain how it works.
 - ✓ As a class, students compare each of the design solutions based on how well they meet criteria and constraints, giving evidence to support their thinking. When giving feedback to the groups, students should identify which criteria were/were not met, and how the design might be improved.
 - ✓ Small groups should then have the opportunity to refine their designs based on the feedback from the class.
 - ✓ At every stage, communicating with peers is an important part of the design process, because shared ideas can lead to improved designs. It is also important that students describe the ways in which energy is transferred between objects and from one form to another.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts

Students will conduct research to build their understanding of energy, transfer of energy, and natural sources of energy. Students will recall relevant information from in-class investigations and experiences and gather relevant information from print and digital sources. They should take notes and categorize information and provide a list of sources. Students also draw evidence from literary and information texts in order to analyze and reflect on their findings. Students can also read, take notes, and construct responses using text and digital resources such as Scholastic News, Nat Geo Kids, Study Jams (Scholastic), Reading A-Z.com, NREL.com, switchenergyproject.com, and NOVA Labs by PBS.

Mathematics

Students reason abstractly and quantitatively as they gather and analyze data during investigations and while conducting research about transfer of energy and energy sources. Students model with mathematics as they represent and/or solve word problems. As students research the environmental effects of obtaining fossil fuels, they might be asked to represent a verbal statement of multiplicative comparison as a multiplication equation. For example, students might find information about a spill that was 5 million gallons of oil and was 40 times larger than a previous oil spill in the same location. They can be asked to represent this mathematically using an equation to determine the number of gallons of oil that were spilled in the previous event.

English Language Arts

Students will conduct a short research project to build their understanding of the transfer of energy (motion, heat, and sound) in force and motion systems. They will need access to a variety of texts and should use information from their class experiences and from print and digital sources to write informative/explanatory texts. As students gather information, they should take notes and categorize information. In their writing, students should detail what they observed as they investigated

simple force and motion systems, describe procedures they followed as they conducted investigations, and use information from their observations and research to explain the patterns of change that occur when objects move and collide. As students participate in discussions and write explanations, they should refer specifically to text, when appropriate.

English Language Arts

Students conduct research that builds their understanding of energy transfers. They will gather relevant information from their investigations and from multiple print or digital sources, take notes, and categorize their findings. They should use this information to construct explanations and support their thinking.

Mathematics

Students can:

- ✓ Solve multistep word problems, using the four operations.
- ✓ Represent these problems using equations with a letter standing for the unknown quantity.
- ✓ Assess the reasonableness of answers using mental computation and estimating strategies, including rounding.

For example, “The class has 144 rubber bands with which to make rubber band cars. If each car uses 6 rubber bands, how many cars can be made? If there are 28 students in the class, how many rubber bands can each car have (if every car has the same number of rubber bands)?”

Students can also analyze constraints on materials, time, or cost to determine what implications the constraints have for design solutions. For example, if a design calls for 20 screws and screws are sold in boxes of 150, how many copies of the design can be made?

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: [All Standards, All Students/Case Studies](#) for vignettes and explanations of the modifications.)

- 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.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#VXmoXcfD_UA).

Research on Student Learning

Students do not distinguish well between heat and temperature when they explain thermal phenomena. Their belief that temperature is the measure of heat is particularly resistant to change. Long-term teaching interventions are required for upper middle-school students to start differentiating between heat and temperature.

During instruction, upper elementary-school students use ideas that give heat an active drive or intent to explain observations of convection currents. They also draw parallels between evaporation and the water cycle and convection, sometimes explicitly explaining the upwards motion of convection currents as evaporation.

Students rarely think energy is measurable and quantifiable. Students' alternative conceptualizations of energy influence their interpretations of textbook representations of energy.

Students tend to think that energy transformations involve only one form of energy at a time. Although they develop some skill in identifying different forms of energy, in most cases their descriptions of energy-change focus only on forms which have perceivable effects. Finally, it may not be clear to students that some forms of energy, such as light and sound can be used to make things happen ([NSDL, 2015](#)).

Students tend to think of force as a property of an object ("an object has force," or "force is within an object") rather than as a relation between objects. In addition, students tend to distinguish between active objects and objects that support or block or otherwise act passively. Students tend to call the active actions "force" but do not consider passive actions as "forces". Teaching students to integrate the concept of passive support into the broader concept of force is a challenging task even at the high-school level ([NSDL, 2015](#)).

Prior Learning

Kindergarten Unit 1: Pushes and Pulls

- Pushes and pulls can have different strengths and directions.
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.

- When objects touch or collide, they push on one another and can change motion.
- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (*secondary*)

Grade 3 Unit 2: Force and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual understandings used at this level.)
- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)

Future Learning**Grade 5 Unit 3: Energy and Matter in Ecosystems**

- The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water).
- Plants acquire their material for growth chiefly from air and water.

Grade 5 Unit 5: Earth Systems

- Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.

Grade 6 Unit 4: Forces and Motion

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

Grade 6 Unit 5: Types of Interactions

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

Grade 7 Unit 7: Organization for Matter and Energy in Organisms

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. *(secondary)*
- Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. *(secondary)*

Grade 7 Unit 8: Earth Systems

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

Grade 8 Unit 3: Stability and Change on Earth

- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

Grade 8 Unit 4: Human Impact

- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Grade 8 Unit 5: Relationships among Forms of Energy

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on their relative positions.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

Grade 8 Unit 6: Thermal Energy

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

Grade 8 Unit 7: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Connections to Other Units

N/A

Sample of Open Education Resources

[Switch Energy Project](#): The Educator Portal provides free access to a documentary, energy labs, videos, and study guides.

[Wind Generator](#): Windmills have been used for hundreds of years to collect energy from the wind in order to pump water, grind grain, and more recently generate electricity. There are many possible designs for the blades of a wind generator and engineers are always trying new ones. Design and test your own wind generator, then try to improve it by running a small electric motor connected to a voltage sensor.

[Thermal Energy Transfer](#): Explore the three methods of thermal energy transfer: conduction, convection, and radiation, in this interactive from WGBH, through animations and real-life examples in Earth and space science, physical science, life science, and technology.

[Spool Racers](#): This resource includes three parts: a video clip from the TV show, Zoom, to introduce the activity, an essay with background information about energy, and a set of printable instructions. Students use a spool, a toothpick, a washer, a rubber band, and a pencil to build a racer. They conduct tests with the racer by varying the number of twists in the rubber band or changing other design features. These websites provide additional ideas for modifying the basic rubber band racer design: <http://www.scienceworld.ca/resources/activities/popcan-porsche> and <http://pbskids.org/designsquad/build/rubber-band-car/>.

[Force and Motion](#): This video segment from IdahoPTV's D4K defines gravity, force, friction and inertia through examples from amusement park rides. Examples and explanations of Sir Isaac Newton's Three Laws of Motion are also included.

[Advanced High-Powered Rockets](#): Students select a flight mission (what they want the rocket to do) and design and construct a high-power paper rocket that will achieve the mission. They construct their rocket, predict its performance, fly the rocket, and file a post-flight mission report. Missions include achieving high altitude records, landing on a "planetary" target, carrying payloads, testing a rocket recovery system, and more.

[The Sound of Science](#): Students are given a scenario/problem that needs to be solved: Their school is on a field trip to the city to listen to a rock band concert. After arriving at the concert, the students find out that the band's instruments were damaged during travel. The band needs help to design and build a stringed instrument with the available materials, satisfying the following criteria and constraints: 1) Produce three different pitched sounds. 2) Include at least one string. 3) Use only available materials. 4) Be no longer than 30 cm / 1 foot. The challenge is divided into 4 activities. Each activity is designed to build on students' understanding of the characteristics and properties of sound. By using what they learn about sound from these activities, students are then encouraged to apply what they know about sound to complete the engineering design challenge.

[Energy Makes Things Happen: The Boy Who Harnessed the Wind](#): This article from Science and Children provides ideas for using the trade book, *The Boy Who Harnessed the Wind*, as a foundation for a lesson on generators. This beautiful book is the inspiring true story of a teenager in Malawi who built a generator from found materials to create much-needed electricity. The lesson allows students to explore the concept of energy transfer using crank generators. Students then design improvements to the crank mechanism on the generator. The lesson may be extended by having students build their own generators.

[Light Your Way](#): Using the engineering design process, students will be designing and building a lantern that they will hypothetically be taking with them as they explore a newly discovered cave. The criteria of the completed lantern will include: hands need to be free for climbing, the lantern must have an on/off switch, it must point ahead when they are walking so they can see in the dark, and the lantern must be able to stay lit for at least 15 minutes. The constraints of the activity will be limited materials with which to build. At the completion of the activity, the students will present their final lantern to the class explaining how they revised and adapted the lantern to meet the criteria of the project. Students will include in the presentation the sketch of the model they created prior to building showing the labeled circuit they designed. This activity was one of numerous engineering lessons from the Virginia Children's Engineering Council geared towards Grades 1-5. <http://www.childrensengineering.org/technology/designbriefs.php>.

Teacher Professional Learning Resources

Assessment for the Next Generation Science Standards

The presenters were Joan Herman, Co-Director Emeritus of the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) at UCLA; and Nancy Butler Songer, Professor of Science Education and Learning Technologies, University of Michigan.

Dr. Herman began the presentation by summarizing a report by the National Research Council on assessment for the Next Generation Science Standards (NGSS). She talked about the development of the report and shared key findings. Next, Dr. Songer discussed challenges for classroom implementation and provided examples of tasks that can be used with students to assess their proficiency on the NGSS performance expectations.

View the [resource collection](#).

Continue discussing this topic in the [community forums](#).

NGSS Crosscutting Concepts: Patterns

The presenter was Kristin Gunckel from the University of Arizona. Dr. Gunckel began the presentation by discussing how patterns fit in with experiences and explanations to make up scientific inquiry. Then she talked about the role of patterns in NGSS and showed how the crosscutting concept of patterns progresses across grade bands. After participants shared their ideas about using patterns in their own classrooms, Dr. Gunckel shared instructional examples from the elementary, middle school, and high school levels.

NGSS Crosscutting Concepts: Structure and Function

The presenters were Cindy Hmelo-Silver and Rebecca Jordan from Rutgers University. Dr. Hmelo-Silver and Dr. Jordan began the presentation by discussing the role of the crosscutting concept of structure and function within NGSS. They then asked participants to think about the example of a sponge and discuss in the chat how a sponge's structure relates to its function. The presenters introduced the Structure-Behavior-Function (SBF) theory and talked about the importance of examining the relationships between mechanisms and structures. They also discussed the use of models to explore these concepts.

NGSS Core Ideas: Energy

The presenter was Jeff Nordine of the San Antonio Children's Museum. Ramon Lopez from the University of Texas at Arlington provided supporting remarks. The program featured strategies for teaching about physical science concepts that answer questions such as "How is energy transferred between objects or systems?" and "What is meant by conservation of energy?"

Dr. Nordine began the presentation by talking about the role of disciplinary core ideas within NGSS and the importance of energy as a core idea as well as a crosscutting concept. He then shared physicist Richard Feynman's definition of energy and related it to strategies for teaching about energy. Dr. Nordine talked about the elements of the energy core idea and discussed common student preconceptions.

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NGSS Crosscutting Concepts: Stability and Change

The presenter was Brett Moulding, director of the Partnership for Effective Science Teaching and Learning. Mr. Moulding began the web seminar by defining stability and change and discussing the inclusion of this concept in previous standards documents such as the National Science Education Standards (NSES). Participants

brainstormed examples of science phenomena that can be explained by using the concept of stability and change. Some of their ideas included Earth's orbit around the Sun, carrying capacity of ecosystems, and replication of DNA. Mr. Moulding then discussed the role of stability and change within NGSS. Participants again shared their ideas in the chat, providing their thoughts about classroom implementation of this crosscutting concept.

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NGSS Appendix I – Appendix I provides an explanation how engineering is treated in the NGSS. Engineering Design in the NGSS The Next Generation Science Standards (NGSS) represent a commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to grade 12.

NGSS Crosscutting Concepts: Energy and Matter—Flows, Cycles, and Conservation

The presenters were Charles W. (Andy) Anderson and Joyce Parker from Michigan State University. Dr. Anderson and Dr. Parker began the web seminar by discussing the role of energy and matter as a crosscutting concept. They talked about energy and matter at different scales, from the atomic to the macroscopic. The presenters shared information about how students learn about this crosscutting concept and how to address preconceptions. They then described instructional strategies such as modeling that can help students better understand the flow of energy and matter.

NGSS Crosscutting Concepts: Scale, Proportion, and Quantity

The presenters were Amy Taylor and Kelly Riedinger from the University of North Carolina Wilmington. Dr. Taylor began the presentation by discussing the definition of scale. Next, Dr. Riedinger talked about the role of scale, proportion, and quantity in NGSS. Participants shared their own experiences teaching about scale in the classroom before the presenters described additional instructional strategies that can provide students with a real-world understanding of this crosscutting concept. Dr. Taylor and Dr. Riedinger showed examples of activities from elementary, middle, and high school. They shared video clips and other resources that can help educators build their capacity for teaching about scale.

Appendix A: NGSS and Foundations for the Unit

Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. [Assessment Boundary: Assessment does not include quantitative measurements of energy.] ([4-PS3-2](#))

Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. <i>[Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]</i> (4-ESS3-1)		
Use evidence to construct an explanation relating the speed of an object to the energy of that object. <i>[Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]</i> (4-PS3-1)		
Ask questions and predict outcomes about the changes in energy that occur when objects collide. <i>[Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.]</i> <i>[Assessment Boundary: Assessment does not include quantitative measurements of energy.]</i> (4-PS3-3)		
Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.* <i>[Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.]</i> <i>[Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.]</i> (4-PS3-4)		
Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)		
Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. (3-5-ETS1-2)		
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. (3-5-ETS1-3)		
The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Students build a model of an amusement park ride called the Twist-o-Matic. They use the model to carry out an investigation to examine the relationship between energy and speed. Students analyze and interpret data from their models, comparing the speed of the ride using a thin versus thick rubber band. Students build a model of a roller coaster and carry out an investigation using marbles. Students analyze and interpret data from the model to explain the connection between height, energy, and speed. Students also start to build an understanding of	DCIs: PS3.B, Foundational for PS3.A: When something is moving, it has energy. Moving things get their energy from stored energy, and energy can be stored in different ways (gasoline, batteries, food, springs, and rubber bands). Students discover that the faster an object is moving, the more energy it has. They compare models that use thin rubber bands and thick rubber bands to determine how differences in stored energy directly relate to the speed of the object. DCIs: PS3.A: Giving something “height” (putting it up high) is another way to store energy. When the	Students explore how energy can be stored and released using a rubber band. The amount of energy that is put into the system is related to the speed of the model spinning around. Students consider how energy is stored, released, and transferred in a system as they experiment with their marble roller coasters. Students consider how energy is stored and released in a system as they experiment with their marble roller coasters.

energy transfer as they observe what happens when additional marbles (additional collisions) are added to the model. Students conduct an investigation using a model roller coaster to determine how energy can be stored in the hills of the coaster. Students analyze and interpret data from the model to understand that marbles must start at the tops of hills so that they will have enough energy to reach the goal at the end of the track. Students begin to design a chain reaction machine. They start by figuring out how to connect two components of the chain reaction: the lever and the slide. This is the basis of the machine they will further develop in Lesson 5. Students design a chain reaction machine that displays a message at the end. The chain reaction machines use multiple components that transfer energy from one part to the next. Students design a flashlights using batteries, lights and tin foil. Students experiment with different ways of constructing their flashlights so that they turn on and off. Students build a paper spinner and conduct an investigation to explain how heat makes things move. Students evaluate the advantages and disadvantages of alternative energy sources to power a town. They obtain and evaluate information about the needs of each source of energy and analyze and interpret data about the town's resources.	object falls or drops, that stored energy is released: this explains why roller coasters work, but also bicycling downhill or skiing. The higher up you place an object, the more energy you store in it, and the faster it goes when released or dropped. When an object collides with another object, some of its energy is transferred to the object and some is transferred to the air. DCIs: PS3.B Something that's falling only has as much energy as was stored in it in the first place. This is why you can notice a pattern with roller coasters - the first hill is always the highest. When an object collides with another object, some of its energy is transferred to the object and some is transferred to the air. DCIs: PS3.A, PS3.C, ETS1.A We can invent devices that convert stored energy into movement, and transfer that energy to various other objects along a pathway. DCIs: PS3.A, PS3.C, ETS1.A Engineers are people who design or invent solutions to problems by using knowledge of science. All engineers think about what their goal is, come up with multiple ideas, test those ideas out, and repeatedly fail until they figure out what works. DCIs: PS3.B, ETS1.A Electricity--the stuff from our outlets and batteries--is a form of energy that we use to produce movement, but also light, heat, and more. Just like the energy in a chain reaction machine, electricity moves along a path and so can be transferred from one place to another. We can use such knowledge about electrical energy to design solutions to problems (such as flashlights for seeing in the dark). DCIs: PS3.B, PS3.D The invention of the engine was a monumental step forward for human transportation; it used heat energy released from burning fuel to	Students consider the ways in which energy can be stored, released, and transferred as they trace the path of energy through a chain reaction. Students consider the ways in which energy can be stored and released as they trace the path of energy through a chain reaction. Electricity is a form of energy that can be stored (such as in batteries) and transferred via wires, where it is used to produce not only movement, but also light, heat, and more. Heat is a form of energy that can be transferred to create movement. Natural resources such as coal, the sun, wind, and wood can be used for energy. Using these resources (cause) can damage the environment (effect).
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	move people and goods over long distances much more safely, cheaply, and quickly. Engines are chain reaction machines--heat is transferred through a device to create movement! DCIs: PS3.D, ESS3.A Some natural resources such as wood, coal, and natural gases can be burned to release energy. Unfortunately, burnable sources of energy release smoke and cause air pollution. Many scientists are exploring alternative natural sources of energy such as solar, wind, and water. These natural sources don't require burning to release energy.	
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English Language Arts	Mathematics
Conduct short research projects that build knowledge through investigation of different aspects of a topic. (4-PS3-2),(4-ESS3-1) W.4.7 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. (4-PS3-2),(4-ESS3-1) W.4.8 Draw evidence from literary or informational texts to support analysis, reflection, and research. (4-ESS3-1) W.4.9 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS3-1) RI.4.1 Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text. (4-PS3-1) RI.4.3 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-PS3-1) RI.4.9 Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (4-PS3-1) W.4.2 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. (3-5-ETS1-2) RI.5.1 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (3-5-ETS1-2) RI.5.1	Reason abstractly and quantitatively. (4-ESS3-1),(3-5-ETS1-2),(3-5-ETS1-3) MP.2 Model with mathematics. (4-ESS3-1),(3-5-ETS1-2),(3-5-ETS1-3) MP.4 Interpret a multiplication equation as a comparison, e.g., interpret $35 = 5 \times 7$ as a statement that 35 is 5 times as many as 7 and 7 times as many as 5. Represent verbal statements of multiplicative comparisons as multiplication equations. (4-ESS3-1) 4.OA.A.1 Solve multistep word problems posed with whole numbers and having whole-number answers using the four operations, including problems in which remainders must be interpreted. Represent these problems using equations with a letter standing for the unknown quantity. Assess the reasonableness of answers using mental computation and estimation strategies including rounding. (4-PS3-4) 4.OA.A.3 Mathematics - Operations and Algebraic Thinking (3-ETS1-1),(3-ETS1-2) 3.OA Use appropriate tools strategically. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3) MP.5 Operations and Algebraic Thinking (3-ETS1-1),(3-ETS1-2) 3-5.OA

Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (3-5-ETS1-2) **RI.5.9**

Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (3-5-ETS1-1),(3-5-ETS1-3) **W.5.7**

Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. (3-5-ETS1-1),(3-5-ETS1-3) **W.5.8**

Draw evidence from literary or informational texts to support analysis, reflection, and research. (3-5-ETS1-1),(3-5-ETS1-3) **W.5.9**