INTRODUCTION TO PERFORMANCE EXPECTATIONS

“The NGSS are standards or goals, that reflect what a student should know and be able to do; they do not dictate the manner or methods by which the standards are taught. . . . Curriculum and assessment must be developed in a way that builds students’ knowledge and ability toward the PEs [performance expectations]” (Next Generation Science Standards, 2013, page xiv).

This chapter shows how the NGSS Performance Expectations were bundled in the Energy Module to provide a coherent set of instructional materials for teaching and learning.

This chapter also provides details about how this FOSS module fits into the matrix of the FOSS Program (page 45). Each FOSS module K–5 and middle school course 6–8 has a functional role in the FOSS conceptual frameworks that were developed based on a decade of research on science education and the influence of A Framework for K–12 Science Education (2012) and Next Generation Science Standards (NGSS, 2013).

The FOSS curriculum provides a coherent vision of science teaching and learning in the three ways described by the NRC Framework. First, FOSS is designed around learning as a developmental progression, providing experiences that allow students to continually build on their initial notions and develop more complex science and engineering knowledge. Students develop functional understanding over time by building on foundational elements (intermediate knowledge). That progression is detailed in the conceptual frameworks.

Second, FOSS limits the number of core ideas, choosing depth of knowledge over broad shallow coverage. Those core ideas are addressed at multiple grade levels in ever greater complexity. FOSS investigations at each grade level focus on elements of core ideas that are teachable and learnable at that grade level.

Third, FOSS investigations integrate engagement with scientific ideas (content) and the practices of science and engineering by providing firsthand experiences.

Teach the module with the confidence that the developers have carefully considered the latest research and have integrated into each investigation the three dimensions of the Framework and NGSS, and have designed powerful connections to the Common Core State Standards for English Language Arts.
Disciplinary Core Ideas Addressed

The Energy Module connects with the NRC Framework 3–5 grade band and the NGSS performance expectations for grade 4. The module focuses on core ideas for physical sciences.

Physical Sciences

Framework core idea PS2: Motion and Stability: Forces and Interactions—How can one explain and predict interactions between objects and within systems of objects?

- **PS2.B: Types of interactions**
  What underlying forces explain the variety of interactions observed? [Objects in contact exert forces on each other (friction, elastic pushes and pulls). Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact—for example, magnets push or pull at a distance. The sizes of the forces in each situation depend on the properties of the objects and their distances apart, and for forces between two magnets, on their orientation relative to each other. The gravitational force of Earth acting on an object near Earth’s surface pulls that object toward the planet’s center.]

The following NGSS Grade 3 Performance Expectations for PS2 are derived from the Framework disciplinary core ideas above.

- **3-PS2-3.** Ask questions to determine cause-and-effect relationships of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.]
Framework core idea PS3: Energy—How is energy transferred and conserved?

• PS3.A: Definitions of energy
  What is energy? [The faster a given object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)]

• PS3.B: Conservation of energy and energy transfer
  What is meant by conservation of energy? How is energy transferred between objects or systems? [Energy is present whenever there are moving objects, sound, light, or heat. Light also transfers energy from place to place. For example, energy radiated from the Sun is transferred to Earth by light. When this light is absorbed, it warms Earth’s land, air, and water and facilitates plant growth. 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 from the energy of motion (e.g., moving water driving a spinning turbine).]

• PS3.C: Relationship between energy and forces
  How are forces related to energy? [When objects collide, the contact forces transfer energy to change the object’s motions. Magnets can exert forces on other magnets or on magnetizable materials, thereby transferring energy (e.g., in the form of motion) even when the objects are not touching.]

• PS3.D: Energy in chemical processes and everyday life
  How do food and fuel provide energy? If energy is conserved, why do people say it is produced or used? [The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use—for example, the stored energy of water behind a dam is released so that it flows downhill and drives a turbine generator to produce electricity. Food and fuel also release energy when they are burned or digested. When machines or animals “use” energy, most often the energy ends up transferred to heat in the surrounding environment. The energy released by burning fuel or digested food was once energy from the Sun that was captured by plants. (Boundary: The fact that plants capture energy from sunlight is introduced at this level, but details of photosynthesis are not.)
It is important to be able to concentrate energy so that it is available for use where and when it is needed. For example, batteries are physically transportable energy storage devices, whereas electricity generated by power plants is transferred from place to place through distribution systems.

The following NGSS Grade 4 Performance Expectations for PS3 are derived from the Framework disciplinary core ideas above.

- **4-PS3-1.** Use evidence to construct an explanation relating the speed of an object to the energy of that object. [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.]

- **4-PS3-2.** 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-PS3-3.** Ask questions and predict outcomes about the changes in energy that occur when objects collide. [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [Assessment Boundary: Assessment does not include quantitative measurements of energy.]

- **4-PS3-4.** Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. [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.] [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.]

**Framework core idea PS4: Waves and their applications in technologies for information transfer—How are waves used to transfer energy and information?**

- **PS4.A: Wave properties**  
  *What are the characteristic properties and behaviors of waves?* [Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). Waves can add or cancel one another as they cross, depending on their relative phase*
(i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

Earthquakes cause seismic waves, which are waves of motion in Earth’s crust.

- **PS4.B: Electromagnetic radiation**
  *What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there?* [An object can be seen when light reflected from its surface enters the eyes; the color people see depends on the color of the available light sources as well as the properties of the surface. The stress is on understanding that light traveling from the object to the eye determines what is seen.]

- **PS4.C: Information technologies and instrumentation**
  *How are instruments that transmit and detect waves used to extend human senses?* [High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa.]

The following NGSS Grade 4 Performance Expectations for PS4 are derived from the Framework disciplinary core ideas above.

- **4-PS4-1.** Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.] [Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.]

- **4-PS4-2.** Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen. [Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.]

- **4-PS4-3.** Generate and compare multiple solutions that use patterns to transfer information. [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1’s and 0’s representing black and white to send information about a picture, and using Morse code to send text.]
Earth and Space Sciences

Framework core idea ESS3: Natural resources—How do Earth’s surface processes and human activities affect each other?

- ESS3.A: Natural resources
  * How do humans depend on Earth’s resources? [All materials, energy, and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.]

The following NGSS Grade 4 Performance Expectations for ESS3 is derived from the Framework disciplinary core idea above.

- **4-ESS3-1.** Obtain and combine information to describe that energy and fuels are derived from natural resources and that their uses affect the environment. [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.]
Engeneering, Technology, and Applications of Science

Framework core idea ETS1: Engineering design—How do engineers solve problems?

• ETS1.A: Defining and delimiting an engineering problem
  What is a design for? What are the criteria and constraints of a successful solution? [Possible solutions to a problem are limited by available materials and resources (constraints). 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.]

• ETS1.B: Developing possible solutions
  What is the process for developing potential design solutions? [Research on a problem should be carried out before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. Testing a solution involves investigating how well it performs under a range of likely conditions. Tests are often designed to identify failure points or difficulties, which suggest the elements of a design that need to be improved. At whatever stage, communication with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.]

• ETS1.C: Optimizing the design solution
  How can the various proposed design solutions be compared and improved? [Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.]

The following NGSS Grades 3–5 Performance Expectations for ETS1 are derived from the Framework disciplinary core ideas above.

• 3-5-ETS1-1. 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-ETS1-2. 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-ETS1-3. 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.
Science and Engineering Practices Addressed

1. Asking questions and defining problems
   - Ask questions about what would happen if a variable is changed.
   - Ask questions that can be investigated based on patterns such as cause-and-effect relationships.

2. Developing and using models
   - Develop a model using an analogy, example, or abstract representation to describe a scientific phenomena.
   - Develop or use models to describe and predict phenomena.
   - Use a model to test cause-and-effect relationships or interactions concerning the functioning of a natural system.

3. Planning and carrying out investigations
   - 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.
   - Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
   - Make predictions about what would happen if a variable changes.

4. Analyzing and interpreting data
   - Represent data in tables and/or various graphical displays to reveal patterns that indicate relationships.
   - Analyze and interpret data to make sense of phenomena using logical reasoning.
   - Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
   - Analyze data to refine a problem statement or the design of a proposed object, tool, or process.
   - Use data to evaluate and refine design solutions.

5. Using mathematics and computational thinking
   - Organize simple data sets to reveal patterns that suggest relationships.
6. Constructing explanations and designing solutions

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Identify the evidence that supports particular points in an explanation.
- Apply scientific ideas to solve design problems.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

7. Engaging in argument from evidence

- Construct an argument with evidence, data, and/or a model.
- Use data to evaluate claims about cause and effect.
- Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

8. Obtaining, evaluating, and communicating information

- Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.
- Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.
- Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media, such as tables, diagrams, and charts.
Crosscutting Concepts Addressed

**Patterns**
- Similarities and differences in patterns can be used to sort and classify natural phenomena.
- Patterns of change can be used to make predictions.
- Patterns of change can be used as evidence to support an explanation.

**Cause and effect**
- Cause-and-effect relationships are routinely identified and used to explain change.

**Systems and system models**
- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.
- A system can be described in terms of its components and their interactions.

**Energy and matter**
- Energy can be transferred in various ways and between objects.
Connections: Understandings about the Nature of Science

Scientific investigations use a variety of methods.

- Scientific methods are determined by questions. Scientific investigations use a variety of methods, tools, and techniques.

Scientific knowledge is based on empirical evidence.

- Science findings are based on recognizing patterns.
- Scientists use tools and technologies to make accurate measurements and observations.

Scientific knowledge assumes an order and consistency in natural systems.

- Science assumes consistent patterns in natural systems.

Science is a human endeavor.

- Men and women from all cultures and backgrounds choose careers as scientists and engineers. Most scientists and engineers work in teams. Science affects everyday life. Creativity and imagination are important to science.

Connections to Engineering, Technology, and Applications of Science

- Interdependence of science, engineering, and technology. Science and technology support each other. Knowledge of relevant scientific concepts and research findings is important in engineering. Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies.

- Influence of science, engineering, and technology on society and the natural world. Engineers improve existing technologies or develop new ones. Over time, people’s needs and wants change, as do their demands for new and improved technologies. When new technologies become available, they can bring about changes in the way people live and interact with one another.
FOSS CONCEPTUAL FRAMEWORK

In the last half decade, teaching and learning research has focused on learning progressions. The idea behind a learning progression is that core ideas in science are complex and wide-reaching, requiring years to develop fully—ideas such as the structure of matter or the relationship between the structure and function of organisms. From the age of awareness throughout life, matter and organisms are important to us. There are things students can and should understand about these core ideas in primary school years, and progressively more complex and sophisticated things they should know as they gain experience and develop cognitive abilities. When we as educators can determine those logical progressions, we can develop meaningful and effective curriculum for students.

FOSS has elaborated learning progressions for core ideas in science for kindergarten through grade 8. Developing a learning progression involves identifying successively more sophisticated ways of thinking about a core idea over multiple years.

If mastery of a core idea in a science discipline is the ultimate educational destination, then well-designed learning progressions provide a map of the routes that can be taken to reach that destination. . . . Because learning progressions extend over multiple years, they can prompt educators to consider how topics are presented at each grade level so that they build on prior understanding and can support increasingly sophisticated learning. (National Research Council, A Framework for K–12 Science Education, 2012, p. 26)

The FOSS modules are organized into three domains: physical science, earth science, and life science. Each domain is divided into two strands, as shown in the table “FOSS Next Generation—K–8 Sequence.” Each strand represents a core idea in science and has a conceptual framework.

- Physical Science: matter; energy and change
- Earth and Space Science: dynamic atmosphere; rocks and landforms
- Life Science: structure and function; complex systems

The sequence in each strand relates to the core ideas described in the NRC Framework. Modules at the bottom of the table form the foundation in the primary grades. The core ideas develop in complexity as you proceed up the columns.
Information about the FOSS learning progression appears in the conceptual frameworks (pages 47 and 57), which shows the structure of scientific knowledge taught and assessed in this module, and the content sequence (pages 58–59), a graphic and narrative description that puts this single module into a K–8 strand progression.

FOSS is a research-based curriculum designed around the core ideas described in the NRC Framework. The FOSS module sequence provides opportunities for students to develop understanding over time by building on foundational elements or intermediate knowledge leading to the understanding of core ideas. Students develop this understanding by engaging in appropriate science and engineering practices and exposure to crosscutting concepts. The FOSS conceptual frameworks therefore are more detailed and finer-grained than the set of goals described by the NGSS performance expectations (PEs). The following statement reinforces the difference between the standards as a blueprint for assessment and a curriculum, such as FOSS.

Some reviewers of both public drafts [of NGSS] requested that the standards specify the intermediate knowledge necessary for scaffolding toward eventual student outcomes. However, the NGSS are a set of goals. They are PEs for the end of instruction—not a curriculum. Many different methods and examples could be used to help support student understanding of the DCIs and science and engineering practices, and the writers did not want to prescribe any curriculum or constrain any instruction. It is therefore outside the scope of the standards to specify intermediate knowledge and instructional steps. (Next Generation Science Standards, 2013, volume 2, p. 342)
BACKGROUND FOR THE CONCEPTUAL FRAMEWORK in Energy

Scientists have identified four forces that drive and control actions in the universe. From weakest to strongest, they are gravity, weak nuclear, electromagnetic, and strong nuclear. Gravity, the weakest of the four, acts to attract masses toward each other. The strong nuclear force, the strongest of the four, binds the atomic nucleus together. The weak nuclear force produces radioactivity in certain materials. The electromagnetic force does everything else. It is responsible for most of the phenomena that we describe as electricity, magnetism, light, and heat. It is the force that drives the complex process of life itself.

Early Awareness of Magnetism

Magnetism was first recognized as a property of a naturally occurring mineral that today is called lodestone. About 600 BCE (before the common era), Greek shepherds noted that bits of a certain kind of stone would stick to the iron tips of their staffs and the iron nails in their sandals, but nothing besides the novelty of the phenomenon was understood.

As early as 1000 CE, people knew that if pieces of lodestone were floated on corks placed in water, the stones always oriented north/south, and could be used as crude compasses. An account of suspended magnetic compasses was written in Chinese by Shen Kua in 1088. In 1269, French engineer Pierre de Maricourt discovered that the magnetism in lodestone can be detected and described as lines of force, and that the magnetic phenomenon has two different natures or poles. In 1600, William Gilbert tested magnetic phenomena extensively and found that the two ends of a magnet always behave differently. He called the two ends the north pole and the south pole. He also found that opposite poles attract and similar poles repel one another. His work explained the behavior of the lodestone compass. He speculated that the entire Earth was a magnet, complete with its own set of poles.

Early Awareness of Electricity

Electric phenomena were first investigated systematically by the Greeks several hundred years BCE. They found that rubbing a piece of amber with cloth gave amber the ability to attract small scraps of straw. What they discovered was static electricity, the electricity that makes your
CONCEPTUAL FRAMEWORK
Physical Science, Energy and Change:
Energy

Motion and Stability: Forces and Interactions
Concept A  The motion of an object is determined by the sum of the forces (pushes and pulls) acting on it.
  • Any change of motion requires a force. Each force has a strength and a direction.
  • An object at rest typically has multiple forces acting on it, but they add to give a zero net force (they are balanced).
Concept B  All interactions between objects arise from a few types of forces, primarily gravity and electromagnetism.
  • The magnitude of the forces depends on the properties of the objects and their distances apart and, for magnets, on their orientation relative to each other.

Energy Transfer and Conservation
Concept A  Energy is a quantitative property (condition) of a system that depends on the motion and interactions of matter and radiation within the system.
  • Electricity (electric current) transfers energy that can produce heat, light, sound, and motion. Electricity can be produced from a variety of natural resources and its use can affect the environment.
  • Food and fuel release energy when they are burned or digested. This energy is transferred from the Sun.
  • Kinetic energy is energy of motion; potential energy is energy of position. The faster an object is moving, the more kinetic energy it has. Objects at higher heights have more potential energy.
Concept B  The total change of energy in any system is always equal to the total energy transferred into or out of the system. When two objects interact, each one exerts a force on the other, and these forces can transfer energy.
  • Magnets can exert forces on other magnets and on magnetizable materials, thereby transferring energy even when the objects are not touching.
  • When objects collide, energy can transfer from one object to another, thereby changing their motion.
Concept C  Electromagnetic waves can be detected over a wide range of frequencies; some can be observed by humans, others can be detected by designed technologies.
  • Waves are a repeating pattern of motion that transfers energy from place to place without displacement of matter.
  • An object can be seen when light reflected from its surface enters the eye.
clothes cling, gives you fly-away hair, and zaps you when you grab the door handle after sliding across the car seat. The Greek word for amber was elektron.

During the 17th and 18th centuries, an understanding of electricity slowly developed. Gilbert found that a variety of rubbed surfaces could attract a variety of materials. The attracting force was so widespread, he thought, that it deserved to be named. Other careful investigators discovered that the electric force can move from one place to another through some substances, but not through others. The materials through which the charge can travel are conductors; the others are insulators. In 1752, Ben Franklin performed his famous kite experiment, proving to the world that he was one lucky fellow not to be electrocuted by such a daring act and that, as he suspected, lightning is electricity.

In 1800, a major discovery revolutionized the way we live. Alessandro Volta developed the first battery from silver and zinc disks in a saltwater environment. Volta’s battery produced a continuous flow of electricity rather than an electric surge that could be discharged only once. What followed was a scientific and technological revolution that changed forever the way we live.

**Unification of Magnetism and Electricity**

At the beginning of the 19th century, magnetism and electricity were believed to be completely separate phenomena. This idea changed in 1820, when Hans Christian Oersted discovered that a wire carrying a current deflects a compass needle. The wire acts like a magnet. A decade later, an English physicist named Michael Faraday figured that, if electricity could produce magnetism, magnetism might create electricity. In 1831, he demonstrated that a magnet passing through a coil of wire produced a surge of electricity in the wire. Faraday’s work unified magnetism and electricity as a single force. Moving magnets and coils are the basis of modern generators. Massive coils, driven by steam or falling water, rotate in huge magnetic fields to produce electricity for home and industry.

Since Faraday’s time, the chronicles of electric and magnetic discoveries show advance after advance, from electric motors, generators, and lights to communication devices such as the telegraph, telephone, radio, and television. In the 1940s, some scientists experimented with a poorly conductive crystalline substance called silicon. They discovered that, when traces of impurities are in the material, it conducts electricity in interesting ways. A crystal can act like a switch or a one-way valve,
allowing electricity to flow in only one direction, and can perform other interesting functions. These silicon materials came to be known as semiconductors.

The most famous semiconductor, the transistor, evolved into integrated circuits, which are scores or even millions of transistors and other electronic components compressed into a tiny wafer, or chip, of silicon embedded in hard plastic. Chips allow incredible miniaturization of circuitry. We can now listen to a radio that rides comfortably in our ear, watch television on our wrist, store file cabinets full of paper on a flash drive that fits in our hand, and carry a powerful computer from place to place in a briefcase or pocket. Amazing, and you can rest assured that further miniaturization of electric circuitry is to come.

How Electricity Works

Electric current is the movement of charge. The charge carriers are usually electrons, those subatomic particles that buzz around the nucleus of every atom. Electrons are negatively charged. Inside the nucleus of an atom are protons and neutrons. Protons are positively charged, and neutrons have no charge. Under normal conditions the number of electrons (–) is equal to the number of protons (+), so the net charge of the atom is neutral.

But atoms are often not neutral. During actions as simple as rubbing a rubber rod with a piece of wool, electrons can be “stolen.” In this case, electrons leave the atoms in the wool and attach to atoms in the rubber. Thus the wool ends up with more protons than electrons and the rubber with more electrons than protons. This separation of charge results in a positive electric charge for the wool and a negative electric charge for the rubber. We call the separation, static charge.

Conditions of imbalance are unstable. Electrons tend to move instantaneously to areas of positive electric charge until balance is achieved. If the number of moving electrons is great, we might see them move as a spark. When you slide across the car seat and then touch the door handle, you feel a momentary shock as the electric charges equalize, and then nothing. Electricity that moves in this way is static discharge.

Portable radios (sound), car horns (sound), flashlights (light), and all other familiar electric devices (toasters, hair dryers) use a different form of electricity: current electricity in a circuit. The simplest source of electric current is the dry cell—a battery. Inside are carefully selected chemicals. The chemicals have a predisposition to react with one another, a process
that involves the transfer of charge. The battery is designed so that the chemicals can’t interact directly. To react they must pass electrons from the electron-donor chemical to the electron-receiver chemical through an external pathway. So a battery is an engineered container of chemicals with a potential to drive electrons from one terminal (electrode) to the other when a conductive pathway is provided.

If a continuous pathway connects one electrode to the other and is made of material with loosely associated electrons, the battery will push charge (electrons) through the material. The resulting movement of electrons is electric current. Materials through which electrons move are conductors. The outermost electrons in all metals form a kind of electron sea surrounding the nuclei, making metals good conductors.

If the electrons are tightly attached to the nucleus, or dedicated to forming strong bonds between nuclei, they cannot be induced to move from one atom to the next. No electricity will flow. Such materials are insulators. Rock, wood, plastic, glass, cloth, and paper are all insulators.

The electromotive force is the push that moves the electrons on their way. It is measured in volts. If electricity acted like water, voltage would be the amount of pressure pushing the water through the pipe. The number of electrons actually moving along is current. It is measured in amperes. Following the water analogy, amperage is the amount of water (number of water molecules) in motion. The pathway (pipe) is a circuit. If the pathway allows the electricity to flow, it is a closed circuit; if no electricity can flow, it is an open circuit.

**How Magnetism Works**

Moving charges generate electric current, so those electrons whizzing around every atom's nucleus are generating a localized electric current. Because electric currents produce magnetic fields, every atom in the universe has its own little magnetic field.

In most materials, the electrons spin in different directions, effectively canceling the magnetic fields created around each atom. In a few materials, such as iron, cobalt, and nickel, atoms form magnetic domains that act like little magnets inside the larger structure of the material. In a steel nail, the domains are distributed randomly and have no magnetic effect. If the magnetic domains can be reoriented so that they align in the same direction, the nail will become a magnet.

Magnets can be made in several ways. A very strong magnetic field will reorient some of the magnetic domains in a piece of steel. The stronger the field, the stronger the magnet produced. Also, if a piece of steel is
oriented north/south and you strike it a mighty blow, the magnetic domains will be thrown into a momentary state of chaos, and as they settle down, Earth’s magnetic field will influence their orientation. A magnet can be made with a nail and a hammer in this manner.

Temporary magnets can be made by wrapping coils of insulated wire around a piece of steel and running a current through the wire. The magnetic field created by the current reorients a large number of the magnetic domains while the current is flowing, thus creating an electromagnet. When the current is interrupted, the domains return to their random orientations, and the piece of steel loses its magnetism.

Magnets might pose a hazard in the classroom—not to you and your students, but to any old-fashioned videotapes or other magnetic storage technologies, including credit cards. (CDs and DVDs are optical technologies, not magnetic technologies, so they are not affected by magnets.) The brown magnetic tape and the black part of magnetic storage cards have carefully oriented domains of magnetism. When they interact with an electronic circuit, little pulses of electricity are generated that carry specific messages. If you bring a magnet close to one of these magnetic-storage devices, you can destroy the encoded message by reorienting the little domains of magnetism.

**Primary Source of Energy**

We live 150 million kilometers from a star that radiates energy continuously. The energy streams out in lots of discrete forms, but the most important form for us here on Earth is electromagnetic radiation. Electromagnetic radiation is delivered in a spectrum of specific wavelengths, from radio waves on the long-wavelength, low-energy end of the spectrum to the X-rays and gamma rays at the short-wavelength, high-energy end. In the middle of the spectrum is visible light. Most of the Sun’s energy that reaches Earth’s surface is in the visible and near-visible wavelengths.

Four things can happen to light that falls on materials on Earth (including the atmosphere, water, and organisms): It can pass through unchanged (transmit), pass through but be redirected (refract), bounce off (reflect), or soak in (absorb). When energy is absorbed, the object that absorbed it has more energy. When sunlight falls on the land or sea and is absorbed, it usually changes into heat. Earth maintains a habitable temperature in a potentially inhospitable universe in part because of its “just-right” proximity to a star, bathed in neither too much nor too little energy.
One of the defining characteristics of Earth is that it is liberally covered with plants and other organisms, such as algae, that absorb solar energy. The absorbed energy is not transformed into heat, but rather into chemical bonds. This complex biochemical process is photosynthesis. The energy of the chemical bonds of carbohydrates, fats, and proteins provides the energy that drives the process of life. The energy can be released as needed to run the metabolic processes, such as growth, movement, sensory response, brain function, reproduction, and the millions of other essential operations that together define life.

**Stored Energy**

The energy locked in the bodies of organisms can be transformed for other purposes by humans. Plants, particularly trees, contain a lot of stored energy. That energy produces heat when the plant material burns. Materials that contain stored energy that can produce heat are called fuels. Other examples are fossil fuels, such as coal, petroleum, and natural gas.

**Energy Transmission**

Energy is a property, or perhaps a condition, of matter. Atoms and electrons are always in motion, and motion has energy. When matter absorbs energy, the matter usually heats up. Hot matter has more energy than cold matter. Energy is always moving. The net flow of energy is always from a place of higher energy to a place of lower energy. Two ways that energy gets from one place to another are by radiation and conduction. Radiation is how energy travels through space. Light, heat, X-rays, radio waves, and their ilk transfer by radiation. Conduction transfers energy by contact between molecules—physical contact, such as your hand touching a hot stove and getting burned.

Energy also travels through water as waves. A pebble tossed into a pond creates a disturbance when its contact transfers kinetic energy from the pebble to the water. Waves emanate outward from the source. Eventually little waves “crash” on the shore of the pond, transferring the energy of the wave to the sand and rocks.
Ocean waves develop when energy transfers from wind to water. The energy of waves moves across the ocean until the waves crash on the shore. But the source of the energy, the wind, is itself a product of solar energy. So, in a very real way, ocean waves are just one more manifestation of solar energy.

Energy in electric currents can produce light, heat, sound, and magnetism. The magnetic energy can produce motion in an electric motor. The electric motor is one of the technological icons of Western culture, as so many of the advances in labor saving, convenience, recreation, manufacturing, construction, and so on are enabled or assisted by movement powered by electric motors.

**Motion and Force**

The world is filled with motion. Some motion happens without human intervention: Earth revolves around the Sun, snowflakes fall to the ground, waves surge across the sea, salmon swim up rivers to fulfill their destinies. Other motions are under our control: clock hands faithfully monitor time, jet planes streak across the sky, baseballs fly over center-field fences, bicycles race in the Tour de France. Both natural and designed motions are part of our perception of the world—there is nothing special about them.

What we take for granted is often worthy of contemplation, in part because it is so commonplace. Familiarity can breed a sense of innate understanding where none really exists. We rarely question what makes things move, often resorting to the popular nonexplanation, “that’s the way the world works.”

Forces make things move or, more accurately, make things change their motion. The two natural forces that affect most of the motion we are aware of are the force of gravity and the electromagnetic force. If a grape slips between your fingers in the backyard, the force of gravity will pull it to the ground. If the same grape happens to fall onto the picnic table, the force of gravity will still pull the grape, but it will not fall to the ground. Why? Because the table is pushing up against the grape with a force exactly equal to the force exerted by gravity pulling the grape down. The force opposing the force of gravity in this example, and most others, is the electromagnetic force, expressed in countless molecular interactions in the matter forming the grape and the table.
Wave Forms

Many natural phenomena can be represented as waves. Sound comes from an oscillating force and travels through a medium as a set of repeating energy pulses. Those sound pulses can be represented as a wave and the shape of the wave provides information about the sound. An ocean wave is a repeating pattern of motion in water. The motion transfers energy through the water until the wave crashes on a beach. While the wave is moving across the ocean, it transfers some of its energy to anything floating on its surface. Energy transferred to a buoy, for example, lifts it up to the top of the crest of the wave. After the energy surge of the wave passes, the buoy settles back to the location where it was before the wave came by. The up-and-down motion is a kind of oscillation, back-and-forth motion without going anywhere.

Light is electromagnetic radiation and is represented as waves. The primary source of light is a radiant object. The most familiar radiant object is the Sun, but lamp filaments, flames, flashes of electricity, and fireflies are also primary sources of light. These objects make light.

Light starts from a vibrating charge, like an electron. The vibration creates waves of energy that stream out in all directions. They are called electromagnetic waves. The size of the wave depends on the rate of vibration of the source charge. Rapidly vibrating charges have lots of energy, and the high-frequency waves they produce have lots of energy, too.

All electromagnetic waves, regardless of their frequency, travel at the speed of light (299,792 kilometers per second or 186,000 miles per second) in straight lines until they hit something. The different frequencies of light waves, called wavelengths, are organized into the electromagnetic spectrum. The longest wavelengths are the low-energy radio frequencies. A single radio wave can be a meter or more in length. At the other end of the spectrum are the high-energy
X-rays and gamma rays, with tiny wavelengths that are billionths of a centimeter. Right in the center of the spectrum is a narrow slice of wavelengths known as visible light. The wavelengths of visible light range from 0.00004 cm (violet) to 0.00007 cm (red). It is this small range of wavelengths that we humans exploit for vision. We cannot see longer wavelengths (infrared and longer) or shorter wavelengths (ultraviolet and shorter), although we can feel infrared radiation as heat and sense the effects of ultraviolet radiation when we are careless and get a painful sunburn.

**Vision**

The human eye has evolved photosensors (modified neurons called rods and cones) that turn visible light into electric pulses, which are processed in the brain to effect what we know as vision. Vision is a direct response to light interacting with photoreceptors.

Light can come from a primary source (radiant object) or a secondary source (an object that reflects light). Reflected light is a little different from what we usually consider a reflection, like that from a window or mirror. Reflected light hits an object and is not absorbed, but bounces off in a new direction. Trees, books, people, oranges, shoes, and every other nonluminous object we see—all reflect light.

Light coming from the Sun is a mixture of frequencies of light. The flood of light includes red, yellow, green, blue, orange, and every other color of light mixed together. The net result is white light. When white light falls on an orange, the orange absorbs wavelengths of light selectively, and reflects the rest. The orange reflects only orange light, so that is what enters our eye. And the orange looks . . . orange! Leaves of trees reflect only green light, stop signs absorb everything but red, and so on. That's what happens when white light falls on an object.

What happens when only selected wavelengths of light fall on an object such as a ripe orange? The orange absorbs all colors of light except orange. If you shine a blue light on the orange, the fruit absorbs the blue light and reflects nothing. The orange appears black.
Engineering Design

Science is a discovery activity, a process for producing new knowledge. Scientific knowledge advances when scientists observe objects and events, think about how their observations relate to what is known, test their ideas in logical ways, and generate explanations that integrate the new information into understanding of the natural world. Thus the scientific enterprise is both what we know (content knowledge) and how we come to know it (practices). Scientists engage in a set of practices as they do their work and these are the same practices students use in their science investigations.

Engineers apply that understanding of the natural world to solve real-world problems. Engineering is the systematic approach to finding solutions to problems identified by people in societies. The fields of science and engineering are mutually supportive and scientists and engineers collaborate in their work. Often, acquiring scientific data requires designing and producing new technologies—tools, instruments, machines, and processes—to perform specific functions. The practices that engineers use are very similar to science practices but also involve defining problems and designing solutions.

The process of engineering design, while it involves engineering practices, is considered a separate set of disciplinary core ideas in the Framework and in the NGSS. There are three basic ideas of engineering design: defining the problem, developing possible solutions, and improving the design.

**Defining the problem** involves an understanding of criteria and constraints. In this investigation, the constraints on the design of the electric circuits are the materials available and the time involved. The criteria are the brightness of the lightbulbs or the speed of the motor.

**Developing possible solutions** involves comparing alternative solutions to see which solution best meets the criteria and constraints of the problem. Groups work collaboratively on several circuit designs, testing each design as they work.

**Improving the design** involves testing the prototype using fair tests, trying to control all variables, and changing only one variable at a time. Students need to know that “failure” is not only OK, but expected in engineering design. Having something fail drives you to improve the system and make progress. Collaboration is an important aspect of engineering design; learning from the successes and failures of other design groups can be very productive. Students can engage in engineering practices without fully engaging in the iterative process of design.
In this module, there are two investigations in which students explore the disciplinary core ideas of engineering design in the context of electric circuitry design. But students engage in engineering practices in other investigations without engaging in the full engineering design process. FOSS has a continuum of engagements in the engineering practices and process from short experiences to more in-depth experiences where students reflect on the core ideas about the design process.

<table>
<thead>
<tr>
<th>CONCEPTUAL FRAMEWORK</th>
<th>Engineering Design: Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concept A</strong></td>
<td>Defining and delimiting engineering problems.</td>
</tr>
<tr>
<td></td>
<td>• 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.</td>
</tr>
<tr>
<td><strong>Concept B</strong></td>
<td>Developing possible solutions.</td>
</tr>
<tr>
<td></td>
<td>• Research before designing, testing possible solutions, communicating with peers about possible solutions are all important parts of the design process. Tests are designed to identify inadequacies which will suggest design elements to improve.</td>
</tr>
<tr>
<td><strong>Concept C</strong></td>
<td>Optimizing the design solution.</td>
</tr>
<tr>
<td></td>
<td>• Different solutions need to be tested in order to determine which of them best achieves the most satisfactory solution to the problem, given the criteria and the constraints.</td>
</tr>
</tbody>
</table>
## Energy and Change Content Sequence

This table shows the four FOSS modules and courses that address the content sequence “energy and change” for grades 3–8. Running through the sequence are two progressions—(1) motion and stability: forces and interactions, and (2) energy transfer and conservation. The supporting elements in each module (somewhat abbreviated) are listed. The elements for the **Energy Module** are expanded to show how they fit into the sequence.

<table>
<thead>
<tr>
<th>Module or course</th>
<th>Motion and Stability: Forces and Interactions</th>
<th>Energy Transfer and Conservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic Force (middle school)</td>
<td>• A force is a push or a pull. Net force is the sum of all the forces acting on a mass.</td>
<td>• Kinetic energy is energy of motion; potential energy is dependent on the position of an object within a system.</td>
</tr>
<tr>
<td></td>
<td>• The magnitude of the magnetic force between two interacting magnetic fields decreases with distance.</td>
<td>• Changing the position of an object in an electric or magnetic field changes the potential energy.</td>
</tr>
<tr>
<td></td>
<td>• Magnets are surrounded by an invisible magnetic field. Magnetic materials may become temporary magnets when they interact with magnetic fields.</td>
<td>• Energy sources can be categorized as renewable or nonrenewable.</td>
</tr>
<tr>
<td></td>
<td>• The magnetic field produced by a current-carrying wire can induce magnetism.</td>
<td>• Energy cannot be created or destroyed, only transferred. Every energy use can be described as a sequence of energy transfers.</td>
</tr>
<tr>
<td>Gravity and Kinetic Energy (middle school)</td>
<td>• Gravity is an attractive force between two objects; a falling object increases speed with a constant acceleration due to gravity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• An object in motion will stay in motion (or an object at rest will stay at rest) unless acted on by an external force.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• For interacting objects, the force exerted by one is equal in strength to the force that the second object exerts in opposite direction.</td>
<td></td>
</tr>
<tr>
<td>Energy (grade 4)</td>
<td></td>
<td>• Kinetic energy is energy of moving things; potential energy is energy dependent on the position of an object within a system.</td>
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<tr>
<td></td>
<td></td>
<td>• Kinetic energy is transferred in a collision.</td>
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<tr>
<td></td>
<td></td>
<td>• Kinetic energy is proportional to the mass of a moving object. Increasing the speed of an object increases its kinetic energy by the same factor squared.</td>
</tr>
<tr>
<td>Motion and Matter (grade 3)</td>
<td>• Magnetic forces between a pair of objects do not require that the objects be in contact. The strength of the force depends on the properties of the objects and their distance apart.</td>
<td></td>
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<tr>
<td></td>
<td>• How magnets interact depends on their orientation (sometimes they attract and sometimes they repel).</td>
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</tr>
<tr>
<td></td>
<td>• Gravity is the force that pulls masses toward the center of Earth.</td>
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<tr>
<td></td>
<td>• Any change of motion requires a force. Each force has a strength and direction.</td>
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</tr>
<tr>
<td></td>
<td>• Patterns of motion can be observed; when there are regular patterns of motion, future motions can be predicted.</td>
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</tr>
</tbody>
</table>
NOTE
See the Assessment chapter at the end of this Investigations Guide for more details on how the FOSS embedded and benchmark assessment opportunities align to the conceptual frameworks and the learning progressions. In addition, the Assessment chapter describes specific connections between the FOSS assessments and the NGSS performance expectations.

The NGSS Performance Expectations addressed in this module include:

Physical Sciences
3-PS2-3
4-PS3-1
4-PS3-2
4-PS3-3
4-PS3-4
4-PS4-1
4-PS4-2
4-PS4-3

Earth and Space Sciences
4-ESS3-1

Engineering, Technology, and Applications of Science
3–5 ETS1-1
3–5 ETS1-2
3–5 ETS1-3

See pages 34–39 in this chapter for more details on the Grade 4 NGSS Performance Expectations.

FOSS Conceptual Framework

Energy Module—FOSS Next Generation

Motion and Stability: Forces and Interactions

• Magnets interact with each other and with materials that contain iron.
• Like poles of magnets repel each other; opposite poles attract. The magnetic force declines as the distance between the magnets increases.
• Conductors are materials through which electric current can flow; all metals are conductors.
• Any change of motion requires a force.
• Gravity is a pulling force that acts between all masses.

Energy Transfer and Conservation

• Energy is present whenever there is motion, electric current, sound, light, or heat.
• Electricity (electric current) transfers energy that can produce heat, light, sound, and motion. Electricity can be produced from a variety of sources.
• A circuit is a system that includes a complete pathway through which electric current flows from a source of energy to its components.
• Energy can be generated by burning fossil fuels or harnessing renewable energy sources such as solar, wind, hydroelectric, and geothermal.
• The faster an object is moving, the more energy it has.
• Motion of one object can transfer to motion of other objects in a collision; a larger force causes a larger change.
• Kinetic energy is energy of motion; potential energy is energy of position.
• Waves are a repeating pattern of motion that transfer energy.
• An object is seen when light from an object enters and is detected by the eye.
Connections to Common Core State Standards—ELA

**RF 3**: Know and apply grade-level phonics and word analysis skills in decoding words.

**RF 4**: Read with sufficient accuracy and fluency.

**RI 1**: Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences.

**RI 2**: Determine the main idea of a text and explain how it is supported by key details; summarize the text.

**RI 3**: Explain procedures, ideas, or concepts in a scientific text.

**RI 4**: Determine the meaning of general academic domain-specific words or phrases.

**RI 5**: Describe overall structure of information in a text.

**RI 6**: Compare and contrast a firsthand and secondhand account of the same topic.

**RI 7**: Interpret information presented visually, and explain how the information contributes to an understanding of the text.

**RI 10**: Read and comprehend science texts.

**W 7**: Conduct short research projects that build knowledge through investigation of different aspects of a topic.

**W 8**: Gather relevant information from experiences and print, and categorize the information.

**SL 1**: Engage in collaborative discussions.

**SL 4**: Report on a text in an organized manner, using facts.

**SL 5**: Add visual displays to presentations.

**L 4c**: Consult reference materials.

**Science and Engineering Practices**
- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

**Connections to NGSS by Investigation**

**Inv. 1: Energy and Circuits**
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations
- Obtaining, evaluating, and communicating information

**Inv. 2: The Force of Magnetism**
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations
- Obtaining, evaluating, and communicating information

**Connections to NGSS**

**Cause and effect**

**Systems and system models**

**Energy and matter**

**Patterns**

**Cause and effect**

**Systems and system models**

**Energy and matter**

**Connections to NGSS by Investigation**

**Connections to**

**Common Core State Standards**

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**RF 4**: Read with sufficient accuracy and fluency to support comprehension.

**RI 3**: Explain procedures, ideas, or concepts in a scientific text.

**RI 5**: Describe overall structure of information in a text.

**RI 6**: Compare and contrast a firsthand and secondhand account of the same topic.

**RI 7**: Interpret information presented visually, and explain how the information contributes to an understanding of the text.

**RI 8**: Explain how an author uses reasons and evidence to support particular points in a text.

**W 5**: Strengthen writing by revising.

**SL 1**: Engage in collaborative discussions.

**SL 4**: Report on a text in an organized manner, using appropriate facts and relevant details.
## Disciplinary Core Ideas

### PS3.A: Definitions of energy
- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2)

### PS3.B: Conservation of energy and energy transfer
- 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. (4-PS3-2)

### PS3.D: Energy in chemical processes and everyday life
- The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)

### ETS1.A: Defining and delimiting engineering problems
- Possible solutions to a problem are limited by available materials and resources (constraints). 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. (3–5-ETS1-1)

### ETS1.B: Developing possible solutions
- 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. (3–5-ETS1-2)

### ETS1.C: Optimizing the design solution
- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3–5-ETS1-3)

## Crosscutting Concepts

- Cause and effect
- Systems and system models
- Energy and matter

### Patterns
- Cause and effect
- Energy and matter

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**Connections to NGSS by Investigation**

**Energy Module—FOSS Next Generation**

61
## Science and Engineering Practices

- Defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating, and communicating information

## Inv. 3: Electromagnets

- Asking questions
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

## Inv. 4: Energy Transfer

<table>
<thead>
<tr>
<th>Connections to Common Core State Standards—ELA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI 1: Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences.</td>
</tr>
<tr>
<td>RI 2: Determine the main idea of a text and explain how it is supported by key details; summarize the text.</td>
</tr>
<tr>
<td>RI 3: Determine the meaning of general academic domain-specific words or phrases.</td>
</tr>
<tr>
<td>RI 4: Interpret information presented visually, and explain how the information contributes to an understanding of the text.</td>
</tr>
<tr>
<td>RI 5: Read and comprehend science texts, with scaffolding as needed.</td>
</tr>
<tr>
<td>W 6: Gather relevant information from experiences and print, and categorize the information.</td>
</tr>
<tr>
<td>W 7: Draw evidence from informational texts to support reflection.</td>
</tr>
<tr>
<td>SL 1: Engage in collaborative discussions.</td>
</tr>
<tr>
<td>SL 2: Paraphrase portions of a text read aloud or information presented orally.</td>
</tr>
<tr>
<td>SL 4: Report on a text in an organized manner, using appropriate facts and relevant details.</td>
</tr>
<tr>
<td>SL 5: Add visual displays to presentations.</td>
</tr>
<tr>
<td>L 3: Use knowledge of language and its conventions when writing, speaking, reading, or listening.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connections to Common Core State Standards—ELA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF 4: Read with accuracy and fluency to support comprehension.</td>
</tr>
<tr>
<td>RI 1: Refer to details and examples in a text when explaining.</td>
</tr>
<tr>
<td>RI 2: Determine the main idea of a text.</td>
</tr>
<tr>
<td>RI 3: Determine the meaning of general academic domain-specific words or phrases.</td>
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<tr>
<td>RI 4: Describe overall structure of information in a text.</td>
</tr>
<tr>
<td>RI 5: Compare and contrast two accounts of the same topic.</td>
</tr>
<tr>
<td>RI 6: Interpret information presented visually.</td>
</tr>
<tr>
<td>RI 7: Explain how an author uses evidence to support points.</td>
</tr>
<tr>
<td>RI 8: Integrate information from two texts on the same topic.</td>
</tr>
<tr>
<td>W 2: Write informative/explanatory text.</td>
</tr>
<tr>
<td>W 5: Strengthen writing by revising.</td>
</tr>
<tr>
<td>L 3: Use knowledge of language and its conventions when writing, speaking, reading, or listening.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Connections to Common Core State Standards—ELA</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 6: Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases.</td>
</tr>
</tbody>
</table>
## Disciplinary Core Ideas

<table>
<thead>
<tr>
<th>PS2.B: Types of interactions</th>
<th>PS4.C: Information technologies and instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3, extended from G3, 4-PS3-4)</td>
<td>• Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PS3.B: Conservation of energy and energy transfer</th>
<th>ETS1.C: Optimizing the design solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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. (4-PS3-2, 4-PS3-4)</td>
<td>• Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3–5-ETS1-3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PS3.D: Energy in chemical processes and everyday life</th>
<th>PS3.C: Relationship between energy and forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)</td>
<td>• When objects collide, the contact forces transfer so as to change the objects’ motions. (4-PS3-3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PS3.A: Definitions of energy</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>The faster a given object is moving, the more energy it possesses. (4-PS3-1)</td>
<td>Patterns</td>
</tr>
<tr>
<td>• Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2, 4-PS3-3)</td>
<td>Cause and effect</td>
</tr>
<tr>
<td>PS3.B: Conservation of energy and energy transfer</td>
<td>Systems and system models</td>
</tr>
<tr>
<td>• 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. (4-PS3-2)</td>
<td>Energy and matter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PS3.D: Energy in chemical processes and everyday life</th>
<th>Crosscutting Concepts</th>
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<td>• The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)</td>
<td>Patterns</td>
</tr>
</tbody>
</table>

### Crosscutting Concepts

- **Patterns**
- **Cause and effect**
- **Systems and system models**
- **Energy and matter**
Science and Engineering Practices

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating, and communicating information

Connections to Common Core State Standards—ELA

- RF 4: Read with sufficient accuracy and fluency to support comprehension.
- RI 1: Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from a text.
- RI 2: Determine the main idea of a text and explain how it is supported by key details; summarize the text.
- RI 3: Explain procedures, ideas, or concepts in a scientific text.
- RI 4: Determine the meaning of general academic domain-specific words or phrases.
- RI 5: Describe overall structure of information in a text.
- RI 6: Compare and contrast a firsthand and secondhand account of the same topic.
- RI 7: Interpret information presented visually, and explain how the information contributes to an understanding of the text.
- RI 10: Read and comprehend science texts, with scaffolding as needed.
- W 5: Strengthen writing by revising.
- W 8: Gather relevant information from experiences and print, and categorize the information.
- W 9: Draw evidence from informational texts to support reflection.
- SL 2: Paraphrase portions of a text read aloud.
- SL 4: Report on a text in an organized manner, using appropriate facts and relevant details to support main ideas.
- L 6: Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases.

Inv. 5: Waves

PS3.B: Conservation of energy and energy transfer

- 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. (4-PS3-2, 4-PS3-3)

PS3.D: Energy in chemical processes and everyday life

- The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)

PS4.A: Wave properties

- Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets the beach. (4-PS4-1)

- Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)

PS4.B: Electromagnetic radiation

- An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)

ESS3.A: Natural resources

- Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-PS3-1)
## Disciplinary Core Ideas

<table>
<thead>
<tr>
<th>PS3.B: Conservation of energy and energy transfer</th>
<th>ETS1.A: Defining and delimiting engineering problems</th>
</tr>
</thead>
</table>
|  • 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. (4-PS3-2, 4-PS3-3)  
  • Light also transfers energy from place to place. (4-PS3-2) |
| PS3.D: Energy in chemical processes and everyday life |  |
|  • The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4) |

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## Crosscutting Concepts

- Patterns
- Cause and effect
- Systems and system models
- Energy and matter
## RECOMMENDED FOSS NEXT GENERATION K–8 SCOPE AND SEQUENCE

<table>
<thead>
<tr>
<th>Grade</th>
<th>Physical Science</th>
<th>Earth Science</th>
<th>Life Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Mixtures and Solutions</td>
<td>Earth and Sun</td>
<td>Living Systems</td>
</tr>
<tr>
<td>4</td>
<td>Energy</td>
<td>Soils, Rocks, and Landforms</td>
<td>Environments</td>
</tr>
<tr>
<td>3</td>
<td>Motion and Matter</td>
<td>Water and Climate</td>
<td>Structures of Life</td>
</tr>
<tr>
<td>2</td>
<td>Solids and Liquids</td>
<td>Pebbles, Sand, and Silt</td>
<td>Insects and Plants</td>
</tr>
<tr>
<td>1</td>
<td>Sound and Light</td>
<td>Air and Weather</td>
<td>Plants and Animals</td>
</tr>
<tr>
<td>K</td>
<td>Materials and Motion</td>
<td>Trees and Weather</td>
<td>Animals Two by Two</td>
</tr>
</tbody>
</table>

*Half-length courses

- Physical Science content
- Earth Science content
- Life Science content
- Engineering content