INTRODUCTION TO PERFORMANCE EXPECTATIONS

This chapter provides details about how this FOSS middle school course fits into the matrix of the FOSS Program. 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 *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 scientific and engineering knowledge. Students develop understanding over time by building on foundational elements or intermediate knowledge. Those elements are detailed in the conceptual frameworks.

Second, FOSS limits the number of core ideas, choosing depth of knowledge over comprehensive 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) with the practices of science and engineering by providing students with firsthand experiences.

If this is your first time teaching a FOSS middle school course, you should review this conceptual design material but save an in-depth study of it until after you have experienced the course in the classroom with students. Teach the course 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.

Contents

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DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has four core ideas in physical sciences.

PS1: Matter and its interactions

PS2: Motion and stability: Forces and interactions

PS3: Energy

PS4: Waves and their applications in technologies for information transfer

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC Framework for the middle school grade band to keep the core ideas in a rich and useful context.

The performance expectations related to each core idea are primarily taken from the NGSS for middle school.

Disciplinary Core Ideas Addressed

The **Waves Course** connects with the NRC *Framework* and the NGSS performance expectations for middle school. The course focuses on core ideas for physical sciences and engineering design.

Physical Sciences

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? [A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. A sound wave needs a medium through which it is transmitted.

  Geologists use seismic waves and their reflection at interfaces between layers to prove structures deep in the planet.]

- **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? [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. Lenses and prisms are applications of this effect.

  A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (prisms). However, because light can travel through space, it cannot be a matter wave, like sound or water waves.]

- **PS4.C: Information technologies and instrumentation**
  How are instruments that transmit and detect waves used to extend human senses? [Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. Designers of such devices must understand both the signal and its interactions with matter. Many modern communication devices use digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information.]

The following NGSS grades 6–8 Performance Expectations for PS4 are derived from the Framework disciplinary core ideas above.

- **MS-PS4-1.** Use mathematic representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
- **MS-PS4-2.** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- **MS-PS4-3.** Integrate qualitative scientific and technical information to support the claim that digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

Engineering, 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? [The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (e.g., familiarity with the local climate may rule out certain plants for the school garden.]
- **ETS1.B: Developing possible solutions**
  What is the process for developing potential design solutions? [A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback.]

- **ETS1.C: Optimizing the design solution**
  How can the various proposed design solutions be compared and improved? [There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful.]

The following NGSS grades 6–8 Performance Expectations for ETS1 are derived from the Framework disciplinary core ideas above.

- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the solution to better meet the criteria for success.
- **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Science and Engineering Practices Addressed

1. ***Asking questions and defining problems***
   - Ask questions that arise from careful observation of phenomena, models, or unexpected results; to clarify and/or seek additional information.
   - Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.
   - Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
2. ***Developing and using models***
   - Evaluate limitations of a model for a proposed object or tool.
   - Develop and/or use a model to predict and/or describe phenomena.
   - Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.
3. ***Planning and carrying out investigations***
   - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
   - Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
   - Collect data about the performance of a proposed object, tool, process, or system under a range of conditions.
4. ***Analyzing and interpreting data***
   - Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
   - Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
   - Analyze and interpret data to provide evidence for phenomena.
   - Analyze and interpret data to determine similarities and differences in findings.

SCIENCE AND ENGINEERING PRACTICES

A Framework for K–12 Science Education (National Research Council, 2012) describes eight science and engineering practices as essential elements of a K–12 science and engineering curriculum. All of these practices are incorporated into the learning experiences in the **Waves Course**.

The learning progression for this dimension of the framework is addressed in *Next Generation Science Standards* (National Academies Press, 2013), volume 2, appendix F. Elements of the learning progression for practices recommended for grades 6–8 as described in the performance expectations appear in bullets below each practice.

5. *Using mathematics and computational thinking*

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.
- Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

6. *Constructing explanations and designing solutions*

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- Construct an explanation using models or representations.
- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

7. *Engaging in argument from evidence*

- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

8. *Obtaining, evaluating, and communicating information*

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).
- Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.

Crosscutting Concepts Addressed

Patterns: *Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.*

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Patterns can be used to identify cause-and-effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Cause and effect: *Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.*

- Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.

Scale, proportion, and quantity: *In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.*

- The observed function of natural and designed systems may change with scale.
- Proportional relationships among different types of quantities provide information about the magnitude of properties and processes.
- Phenomena that can be observed at one scale may not be observable at another scale.

Systems and system models: *A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.*

- Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.

Energy and matter: *Tracking energy and matter flows into, out of, and within systems helps to understand the system's behavior.*

- Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).

CROSSCUTTING CONCEPTS

A Framework for K–12 Science Education describes seven crosscutting concepts as essential elements of a K–12 science and engineering curriculum. The learning progression for this dimension of the framework is addressed in volume 2, appendix G, of the NGSS. Elements of the learning progression for crosscutting concepts recommended for grades 6–8, as described in the performance expectations, appear after bullets below each concept.

Structure and function: *The way an object is shaped or structured determines many of its properties and its functions.*

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Connections to the Nature of Science

- **Scientific knowledge is based on empirical evidence.** Scientific knowledge is based on logical and conceptual connections between evidence and explanations. Science disciplines share common rules of obtaining and evaluating empirical evidence.
- **Scientific knowledge assumes an order and consistency in natural systems.** Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Science carefully considers and evaluates anomalies in data and evidence.
- **Science is a human endeavor.** Men and women from different social, cultural, and ethnic backgrounds work as scientists and engineers. Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination, and creativity. Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. Advances in technology influence the progress of science, and science has influenced advances in technology.

Connections to Engineering, Technology, and Applications of Science

- **Interdependence of science, engineering, and technology.** Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward.
- **Influence of science, engineering, and technology on society and the natural world.** All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative for the health of people and the natural environment. The uses of technologies and any limitation on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region over time.

CONNECTIONS

See volume 2, appendix H and appendix J, in the NGSS for more on these connections.

FOSS CONCEPTUAL FRAMEWORK

FOSS has conceptual structure at the course level. The concepts are carefully selected and organized in a sequence that makes sense to students when presented as intended. In the last half decade, research has focused on learning progressions. The idea behind a learning progression is that **core ideas** in science are complex and wide-reaching—ideas such as the structure of matter or the relationship between the distribution and function of organisms. From the age of awareness throughout life, matter and organisms are important to us. There are things we can and should understand about them in our primary school years, and progressively more complex and sophisticated things we should know about them as we gain experience and develop our cognitive abilities. When we as educators can determine those logical progressions, we can develop meaningful and effective curriculum.

FOSS has elaborated learning progressions for core ideas in science for kindergarten through grade 8. Developing the learning progressions involves identifying successively more sophisticated ways of thinking about core ideas 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" (National Research Council, *A Framework for K–12 Science Education*, 2012, page 26).

The FOSS modules (grades K–5) and courses (grades 6–8) are organized into three domains: physical science, earth science, and life science. Each domain is subdivided into two strands, each representing a core scientific idea, as shown in the columns in the table: matter/energy and change, atmosphere and Earth/rocks and landforms, structure and function/complex systems. The sequence of modules and courses in each strand relates to the core ideas described in the national framework. Modules at the bottom of the table form the foundation in the primary grades. The core ideas develop in complexity as they proceed up the columns.

In addition to the science content framework, every course provides opportunities for students to engage in and understand science practices, and many courses explore issues related to engineering practices and the use of natural resources.

The science content used to develop the FOSS courses describes what we want students to learn; the science and engineering practices describe how we want students to learn; and crosscutting concepts stitch the whole effort into a coherent fabric describing the whole natural world. Practices involve a number of habits of mind and philosophical orientations, and these, too, will develop in richness and complexity as students advance through their science studies. Science and engineering practices involve behaviors, so they can be best assessed while in progress. Thus, assessment of practices is based on teacher observation. The indicators of progress include students involved in the many aspects of active thinking, students motivated to learn, and students taking responsibility for their own learning.

FOSS Next Generation—K–8 Sequence

	PHYSICAL SCIENCE		EARTH SCIENCE		LIFE SCIENCE	
	MATTER	ENERGY AND CHANGE	ATMOSPHERE AND EARTH	ROCKS AND LANDFORMS	STRUCTURE/ FUNCTION	COMPLEX SYSTEMS
6–8	Waves; Gravity and Kinetic Energy Chemical Interactions Electromagnetic Force		Planetary Science Earth History Weather and Water		Heredity and Adaptation Populations and Ecosystems Diversity of Life; Human Systems Interactions	
5	Mixtures and Solutions		Earth and Sun		Living Systems	
4		Energy		Soils, Rocks, and Landforms	Environments	
3	Motion and Matter		Water and Climate		Structures of Life	
2	Solids and Liquids			Pebbles, Sand, and Silt	Insects and Plants	
1		Sound and Light	Air and Weather		Plants and Animals	
K	Materials and Motion		Trees and Weather		Animals Two by Two	

BACKGROUND FOR THE CONCEPTUAL FRAMEWORK *in Waves*

Waves

Waves are defined by their repeating patterns and transfer of energy. This simple principle ties together the diverse phenomena of sound traveling through air, water waves traveling through the ocean, and light traveling through the vacuum of space. The waveform has characteristics that can be described and measured: amplitude, wavelength, and frequency.

Mechanical waves must travel through a medium, such as an ocean wave through water, a spring wave through metal, or a sound wave through air. The transfer of energy occurs along the pathway of the wave without bulk displacement of matter. This is why an ocean wave may bob a boat up and down as it passes by, while the boat stays mostly in one place. But the energy of the wave is propagated as the wave travels. When the wave encounters a new medium, the wave and its energy may be absorbed, reflected, or refracted, meaning it is bent to travel in a new direction.

Light can be described as a wave. It does not need to travel through a medium, although it may do so. Light is a form of electromagnetic radiation and can be modeled as either a wave or a particle. At the middle school level, students focus on the wave model to understand electromagnetic radiation.

The electromagnetic spectrum consists of waves from very high frequency/short wavelength (gamma rays) to very low frequency/long wavelength (radio waves) and everything in between. Visible light, which represents the wavelengths detectable by the human eye, lies roughly in the middle of the spectrum. Each color of visible light has a range of wavelengths that define that color.

Just as with mechanical waves, electromagnetic waves traveling from one medium to another are absorbed, reflected, or refracted when they encounter a new medium. This depends on the properties of the medium and the frequency of the wave. When visible light arrives at a surface, some wavelengths of light are typically absorbed, while others are reflected. Only the reflected light will be seen by an onlooker, so an object's color is defined by the light it reflects.

Wave Communications

Because of their ability to transfer energy without displacing matter, waves are useful for communicating over a distance. Sound waves transfer through air patterns of information that humans can discern as speech or music. Humans and other animals evolved complex sensory organs and nervous systems that take advantage of this fact and allow the information to be decoded into meaning.

Light, with its extremely fast speed, provides other opportunities for humans to transmit information. Humans have developed numerous modern technologies that detect and transmit electromagnetic radiation beyond the visible spectrum. Complex information such as images and sound can be digitized and sent as wave pulses. These digitized signals provide reliability in storage and transmission over large distances. The modern communications of humans, in the form of cell phone calls, e-mails, online videos and games, air traffic control systems, TV programming, and more, rely on the human manipulation and transmission of electromagnetic waves.

CONCEPTUAL FRAMEWORK
Physical Sciences, Energy and Change: Waves

Energy Transfer and Conservation

Concept C Waves are a repeating pattern of motion that transfers energy from place to place without displacement of matter. Waves can be detected over a wide range of frequencies; some can be observed by humans, others can be detected by designed technologies.

- A simple wave has a repeating pattern of wavelength, frequency, and amplitude, all of which are related to the energy transferred by the wave.
- Mechanical waves (like sound) require a medium through which they are transmitted.
- Waves interacting with a medium can be absorbed, reflected, or transmitted through the medium.
- A wave model can be used to explain the properties of light (brightness, color, and frequency-dependent bending). Because light can travel through space, it cannot be a mechanical wave (such as sound, spring, or water waves).
- Light travels in straight lines, except at the interface between transparent media where refraction occurs.
- Electromagnetic waves form a spectrum of different wavelengths. Some electromagnetic radiation (visible light) can be detected by humans. An object can be seen when light reflected from its surface enters the eye.
- Information technologies (radio, television, cell phones, wired and wireless computer networks) are examples of instruments that transmit and detect waves to extend human senses. Design engineers must understand both the properties of the wave signal and its interaction with matter.
- Digitized signals (sent as wave pulses) are a reliable way to encode and transmit information.

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 "with precision" means having a clear understanding of specific criteria and constraints in a complex problem that might have a broader societal or environmental impact. When students explore the historical engineering failure of the Tacoma Narrows Bridge, they learn that a limited financial budget can contain real-life designs with dire outcomes.

Developing possible solutions at middle school focuses not only on generating design ideas, but also on a process of evaluating different ideas that have been proposed in a systematic way such as a trade-off matrix to determine the most promising designs. Those most promising designs would be tested and solutions results would be combined into a new solution.

Optimizing the design involves an iterative process of testing the best design, systematically analyzing the results, modifying the design while controlling variables, retesting, comparing results, and again modifying the design. Students may go through this cycle several times in order to optimize the design. 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 course, there is one investigation in which students explore the disciplinary core ideas of engineering design in the context of energy and waves. 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.

CONCEPTUAL FRAMEWORK
Engineering Design: Waves

Concept A **Defining and delimiting engineering problems**

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions.

Concept B **Developing possible solutions**

- A solution needs to be tested and then modified on the basis of the test results in order to improve it.
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- Models of all kinds are important for testing solutions.

Concept C **Optimizing the design solution**

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Physical Science Content Sequence

This table shows all the modules and courses for grades 3–8 in the FOSS content sequence for physical science, with an emphasis on the modules that inform the Energy and Change strand. The supporting elements in these modules (somewhat abbreviated) are listed. The elements for the **Waves Course** are expanded to show how they fit into the sequence.

	ENERGY AND CHANGE	
Module or course	**Motion and Stability: Forces and Interactions**	**Energy Transfer and Conservation**
Waves (middle school)		
Gravity and Kinetic Energy (middle school)	• Gravity is an attractive force between two objects; a falling object increases speed with a constant acceleration due to gravity. • An object in motion will stay in motion (or an object at rest will stay at rest) unless acted on by an external force. • The greater the object's mass, the greater the force needed to change motion. • For interacting objects, the force exerted by one on the second is equal in strength to the force that the second object exerts on the first, but in the opposite direction.	• Kinetic energy is energy of moving things; potential energy is energy dependent on the position of an object within a system. • Kinetic energy is transferred in a collision. • 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.
Electromagnetic Force (middle school)	• A force is a push or a pull. Net force is the sum of all the forces acting on a mass. • Magnets are surrounded by an invisible magnetic field. The magnetic field produced by a current-carrying wire can induce magnetism in iron (electromagnet). • The magnitude of the magnetic force between two interacting magnetic fields decreases as the distance increases.	• Kinetic energy is energy of motion. • Changing the position of an object in an electric or magnetic field changes the potential energy. • Energy cannot be created or destroyed, only transferred. • Every energy use can be described as a sequence of energy transfers. • Energy sources can be categorized.
Energy (grade 4)	• 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 can be generated by burning fossil fuels or harnessing renewable energy. • Electric current transfers energy that can produce heat, light, sound, and motion. • A circuit is a system that includes a pathway through which electric current flows. • Motion of one object can transfer to motion of other objects in a collision. • 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.
Motion and Matter (grade 3)	• 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. • Gravity is the force that pulls masses toward the center of Earth. • Any change of motion requires a force. Each force has a strength and direction.	

Waves	Energy Transfer and Conservation
	• A simple wave has a repeating pattern of wavelength, frequency, and amplitude, all of which are related to the energy transferred by the wave. • Mechanical waves (like sound) require a medium through which they are transmitted. • Waves interacting with a medium can be absorbed, reflected, or transmitted through the medium. • A wave model can be used to explain the properties of light (brightness, color, and frequency-dependent bending). Because light can travel through space, it cannot be a mechanical wave. • Light travels in straight lines, except at the interface between transparent media where refraction occurs. • Electromagnetic waves form a spectrum of different wavelengths. Some electromagnetic radiation (visible light) can be detected by humans. An object can be seen when light reflected from its surface enters the eye. • Information technologies are instruments that transmit and detect waves to extend human senses. Design engineers must understand both the properties of the wave signal and its interaction with matter. • Digitized signals (sent as wave pulses) provide a reliable way to encode and transmit information.

NOTE

See the Assessment chapter in this *Investigations Guide* for more details on how the FOSS embedded and benchmark assessment opportunities align with 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 course include:

Physical Sciences
MS–PS4-1
MS–PS4-2
MS–PS4-3

Engineering Design
MS–ETS1-1
MS–ETS1-2
MS–ETS1-3
MS–ETS1-4

See pages 34–36 in this chapter for more details on the grades 6–8 NGSS Performance Expectations.

CONNECTIONS TO NGSS BY INVESTIGATION

Inv. 1: Make Waves

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations	**Writing—Literacy in Science and Technical Subjects** 2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. 5. With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed. **Speaking and Listening** 4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. **Language** 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS4.A: Wave properties • A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. A sound wave needs a medium through which it is transmitted. **(MS-PS4-1)**		Patterns Systems and system models Energy and matter

Science and Engineering Practices	Connections to Common Core State Standards—ELA
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 Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite specific textual evidence to support analysis of science and technical texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct. 4. Determine the meaning of symbols, key terms, and domain-specific words and phrases as used in text. 5. Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic. 6. Analyze the author's purpose in providing an explanation or discussing an experiment in a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text. 10. Read and comprehend science texts in the grades 6–8 text complexity independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/explanatory texts, scientific procedures/ experiments, or technical processes. 4. Produce clear and coherent writing. 5. With some guidance and support from peers and adults, develop and strengthen writing. 7. Conduct short research projects to answer a question, drawing on several sources. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage effectively in a range of collaborative discussions. 3. Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning. 4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, valid reasoning, and well-chosen details. 5 Integrate multimedia and visual displays into presentations to clarify information. 6. Adapt speech to a variety of contexts and tasks, demonstrating command of formal English. **Language** 4. Determine or clarify the meaning of unknown words. 5. Demonstrate understanding of word relationships. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS4.A: Wave properties • A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. A sound wave needs a medium through which it is transmitted. **(MS-PS4-1, MS-PS4-2)** **ETS1.A: Defining and delimiting an engineering problem** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. **(MS-ETS1-1)** **ETS1.B: Developing possible solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. **(MS-ETS1-4, MS-ETS1-2, MS-ETS1-3)** • Models of all kinds are important for testing solutions. **(MS-ETS1-4)**	**ETS1.C: Optimizing the design solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. **(MS-ETS1-3, MS-ETS1-4)**	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function

Inv. 3: Light Waves

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite specific textual evidence to support analysis of science and technical texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct. 5. Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic. 6. Analyze the author's purpose in providing an explanation or discussing an experiment in a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text. 10. Read and comprehend science texts in the grades 6–8 text complexity independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/explanatory texts, scientific procedures/ experiments, or technical processes. 4. Produce clear and coherent writing. 5. With some guidance and support from peers and adults, develop and strengthen writing. 7. Conduct short research projects to answer a question, drawing on several sources. 8. Gather relevant information from multiple print and digital sources, using search terms effectively. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage effectively in a range of collaborative discussions. 3. Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning. 4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, valid reasoning, and well-chosen details. **Language** 4. Determine or clarify the meaning of unknown words. Use common, grade-appropriate Greek or Latin affixes and roots as clues to the meaning of a word.

Disciplinary Core Ideas		Crosscutting Concepts
PS4.A: Wave properties • Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. **(secondary to HS-ESS2-3)** **PS4.B: 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. **(MS-PS4-2)** • 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. **(MS-PS4-2)** • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. **(MS-PS4-2)** • However, because light can travel through space, it cannot be a matter wave, like sound or water waves. **(MS-PS4-2)**		Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter

Inv. 4: Communication Waves

Science and Engineering Practices	Connections to Common Core State Standards—ELA
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	**Reading—Literacy in Science and Technical Subjects** 1. Cite specific textual evidence to support analysis of science and technical texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 10. Read and comprehend science texts in the grades 6–8 text complexity independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/explanatory texts, scientific procedures/ experiments, or technical processes. 5. With some guidance and support from peers and adults, develop and strengthen writing. 7. Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, valid reasoning, and well-chosen details. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS4.C: Information technologies and instrumentation • Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. **(MS-PS4-3)**		Patterns Scale, proportion, and quantity Structure and function

RECOMMENDED FOSS NEXT GENERATION K–8 SCOPE AND SEQUENCE

Grade	Integrated Middle Grades				
6–8	Heredity and Adaptation*	Electromagnetic Force*	Gravity and Kinetic Energy*	Waves*	Planetary Science
	Chemical Interactions		Earth History		Populations and Ecosystems
	Weather and Water		Diversity of Life		Human Systems Interactions*

**Half-length courses* · *Physical Science content* · *Earth Science content* · *Life Science content* · *Engineering content*

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