SAMPLER

# Waves

## INVESTIGATIONS GUIDE

FOSS™
Next Generation

Full Option Science System
Developed at the Lawrence Hall of Science, University of California, Berkeley
Published and Distributed by Delta Education

Science & Engineering PRACTICES
Disciplinary CORE IDEAS
CROSSCUTTING Concepts

# Active investigation is at the heart of FOSS.

Every student deserves the benefits of science education—not just exposure to scientific phenomena, but the opportunity to make sense of them and authentically apply them to the real world. From its foundations, FOSS® is built to ensure access to all, regardless of background, culture, language, or ability.

The scholars at the Lawrence Hall of Science designed FOSS around the principle of collaborative, active investigation. FOSS effectively engages all students by leveraging their natural curiosity for observable phenomena, a teaching philosophy now considered best practice with the arrival of the Next Generation Science Standards (NGSS).

FOSS lessons help teachers reach all students through phenomena that are local and relevant. This student-centered approach ultimately enhances learning by ensuring that each individual has multiple opportunities to apply their prior knowledge and personal experiences to make sense of phenomena and solve problems. In this way, FOSS makes science accessible and equitable for every student in every classroom.

# Comprehensive packages for complete learning.

FOSS® is more than just a science curriculum or science kit. Your investment in any FOSS course provides you with all the key student and teacher components to deliver world-class science education – no need to spend additional minutes or dollars searching for essential materials. Each element is thoughtfully designed with consideration for your money, space, and precious time.


**“The hands-on group work is amazing. The kids get hands-on experience and can connect ideas about STEM to real-world experiences. The literacy component is great as well.”**

Arielle S., 4th Grade Teacher
*Tell City, IN*

## Equipment Kit

Durable equipment and classroom tested materials, selected and designed expressly for FOSS, lead to successful investigations for all students. Kits include permanent equipment for classes of 32 students (8 groups) with enough consumables for five (5) uses at middle school.

## Investigations Guide

This is the core instructional tool that supports the teacher in facilitating student investigations. Chapters include Overview, Framework and NGSS, Materials, Technology, Assessment, and each detailed Investigation. Available in print and digital.

## FOSS Science Resources

FOSS student reading materials are in-depth articles that connect students’ firsthand experiences to informational text, helping expand understanding from the concrete to the abstract. Available in print, eBook, and audiobook.

## FOSS Technology

FOSSweb on ThinkLink™ offers simulations and virtual investigations. Online activities provide differentiating instruction. Student ebooks and streaming video are also included. Comprehensive teacher preparation videos and instructional slides support teachers.

## Teacher Resources

Provided in print and available digitally, resources include grade-level chapters on sense-making and three-dimensional teaching and learning; connections to Common Core ELA and Math standards; taking FOSS outdoors; access and equity in science; science-centered language development; using science notebooks; and notebook, teacher, and assessment masters.

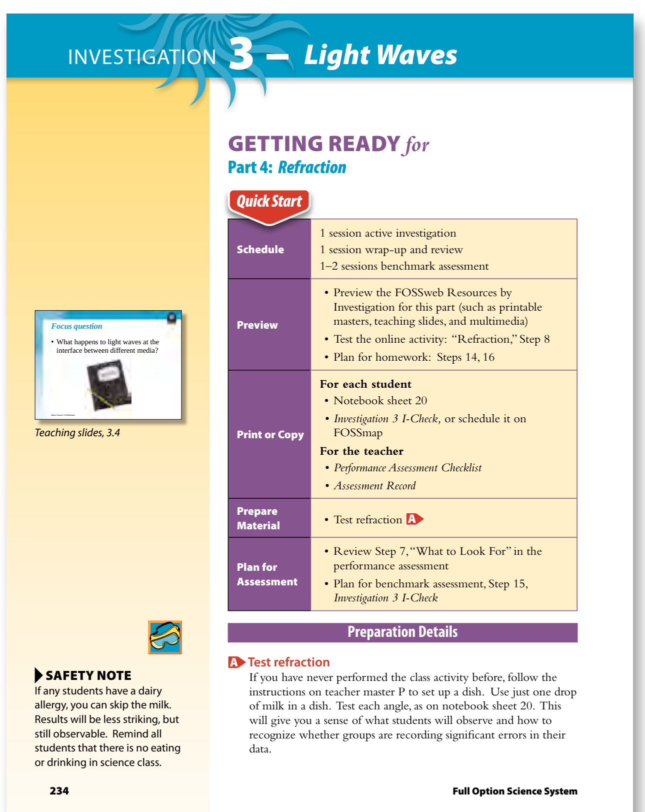
## Spanish Resources

Spanish editions of *FOSS Science Resources* are offered both in print and eBook. FOSSweb on ThinkLInk provides audio files for *FOSS Science Resources*, as well as notebook, assessment, and teacher masters, module vocabulary and definitions, teaching slides, and Focus Questions.

# Materials management made easy.

We believe that students learn science best by doing science. FOSS materials are field-tested to help you provide students with hands-on experiences that engage their minds and build their understanding. We've spent decades working in classrooms to provide comprehensive materials management support for teachers of all levels of experience.

- Investigations Guide with step-by-step instructions to help you through lesson preparation, facilitation, and assessment.
- Teacher preparation videos to provide visuals for important investigation setups.
- Efficient equipment kits, designed for middle schools—outfit your classroom with materials to complete each investigation with five classes of students.
- Handy refill kits replace consumables so you can make the most of your time teaching science.



INVESTIGATION 3 — *Light Waves*

GETTING READY *for*
Part 4: *Refraction*

Quick Start

| | |
|---|---|
| Schedule | 1 session active investigation<br>1 session wrap-up and review<br>1–2 sessions benchmark assessment |
| Preview | • Preview the FOSSweb Resources by Investigation for this part (such as printable masters, teaching slides, and multimedia)<br>• Test the online activity: "Refraction," Step 8<br>• Plan for homework: Steps 14, 16 |
| Print or Copy | **For each student**<br>• Notebook sheet 20<br>• *Investigation 3 I-Check,* or schedule it on FOSSmap<br>**For the teacher**<br>• *Performance Assessment Checklist*<br>• *Assessment Record* |
| Prepare Material | • Test refraction A |
| Plan for Assessment | • Review Step 7, "What to Look For" in the performance assessment<br>• Plan for benchmark assessment, Step 15, *Investigation 3 I-Check* |

Preparation Details

A Test refraction
If you have never performed the class activity before, follow the instructions on teacher master P to set up a dish. Use just one drop of milk in a dish. Test each angle, as on notebook sheet 20. This will give you a sense of what students will observe and how to recognize whether groups are recording significant errors in their data.

Focus question
• What happens to light waves at the interface between different media?

*Teaching slides, 3.4*

SAFETY NOTE
If any students have a dairy allergy, you can skip the milk. Results will be less striking, but still observable. Remind all students that there is no eating or drinking in science class.

234 Full Option Science System

FOSS *Investigations Guides* include a streamlined Quick Start Guide for each part of every investigation that highlights exactly what needs to be printed, set up, or prepared in advance of the lesson.

## New equipment options for middle schools

We listened to middle school teachers from across the country when developing FOSS Next Generation Middle School and now offer greater flexibility in equipping your FOSS classroom or lab. **Ask your Regional Sales Manager** which equipment option is the best fit for you.

| | FULL KIT | LITE KIT |
|---|---|---|
| **Consumable items (refill kits available)** | X | X |
| **Unique, program-specific permanent items** | X | X |
| **Common science lab items (beakers, graduated cylinders, etc.) or items found in multiple FOSS courses** | X | |

**"I love teaching science, but many teachers do not feel confident. FOSS kits are laid out clearly so that a novice teacher can easily guide the investigations. Before FOSS, I had to gather materials myself. Now most materials are included in the kit."**

Robin S., Teacher
*Pennsylvania*

# WAVES
# Grade 8 Course Phenomena Map

## Anchor Phenomenon

**COURSE DRIVING QUESTION(S): How is energy transferred through waves?**

Students engage with the anchor phenomenon of **energy transfer by waves** to explain mechanical waves, electromagnetic waves, and communication technology.

## Firsthand Investigative Phenomena

### INVESTIGATION 1: MAKE WAVES

Students create waves using a metal spring to observe and measure the properties of waves and explore how waves transfer energy..

**GUIDING QUESTION(S):**
What are the properties of all waves?

**FOCUS QUESTIONS FOR PHENOMENA:**
**Part 1:** What is frequency?
**Part 2:** What defines a wave?

### INVESTIGATION 2: WAVE ENERGY

Students study ocean waves to understand mechanical wave energy and apply that learning to a design challenge in which they must soundproof a small model room.

**GUIDING QUESTION(S):**
How do mechanical waves interact with matter?

**FOCUS QUESTIONS FOR PHENOMENA:**
**Part 1:** What is the relationship between wave properties and wave energy?
**Part 2:** How are engineering challenges solved?
**Part 3:** What is the best way to insulate a recording studio from outside sounds?

### INVESTIGATION 3: LIGHT WAVES

Students explain color, reflection, and refraction by studying light waves interacting with media using mirrors, spectroscopes, and lasers.

**GUIDING QUESTION(S):**
How do electromagnetic waves interact with matter?

**FOCUS QUESTIONS FOR PHENOMENA:**
**Part 1:** What happens when light waves interact with matter?
**Part 2:** What do spectra reveal about light?
**Part 3:** Student-generated question, e.g., What makes objects appear as different colors?
**Part 4:** What happens to light waves at the interface between different media?

### INVESTIGATION 4: COMMUNICATION WAVES

Students use lasers and optical fibers to understand how engineers use digitized signals to transfer information efficiently over large distances.

**GUIDING QUESTION(S):**
How can waves be used to transmit information over large distances?

**FOCUS QUESTIONS FOR PHENOMENA:**
**Part 1:** What are some design constraints in fiber optic communications?
**Part 2:** How is sound sent through radio waves?
**Part 3:** How are images sent through radio waves?

## Related Real-World Phenomena

### INVESTIGATION 1 READING EXAMPLES

Students consider how a compression wave has the same characteristics as a transverse wave.

### INVESTIGATION 1 MULTIMEDIA EXAMPLES

Students observe a standing wave to identify wave reflection and measure the wave.

### INVESTIGATION 2 READING EXAMPLES

Students explore the destructive power of a tsunami wave.

### INVESTIGATION 2 MULTIMEDIA EXAMPLES

Students learn how surfers rely on wave energy to catch a ride at one of the world's greatest surf sites.

Students watch footage of the Tacoma Narrows Bridge failure and collapse in order to study the engineering design process.

### INVESTIGATION 3 READING EXAMPLES

Students learn how MRI and x-ray technologies use electromagnetic radiation to improve human health.

Students explain how seismic waves can be used to learn about Earth's interior.

### INVESTIGATION 3 MULTIMEDIA EXAMPLES

Students test how light refracts when passing through various media.

### INVESTIGATION 4 READING EXAMPLES

Students explain how telephones, televisions, cellular phones, and computers transmit information digitally.

### INVESTIGATION 4 MULTIMEDIA EXAMPLES

Students manipulate digitized images to demonstrate the effect of changing the resolution.



The Full Option Science System® is developed at the Lawrence Hall of Science, University of California, Berkeley

# Waves Alignment to Performance Expectations

| Performance Expectations | FOSS | |
|---|---|---|
| | Investigation(s) | Benchmark Assessment |
| **MS-PS4-1:** Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. | **Investigation 1**<br>**Investigation 2** | • Investigation 1, Part 2 Performance Assessment<br>• Investigation 2, Part 3 Notebook Entry<br>• Investigation 1-2 I-Check<br>• Survey/Posttest |
| **MS-PS4-2:** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. | **Investigation 2**<br>**Investigation 3** | • Investigation 2, Part 3 Performance Assessment<br>• Investigation 3, Part 1 Notebook Entry<br>• Investigation 3, Part 4 Performance Assessment<br>• Investigation 3, Part 3 Response Sheet<br>• Investigation 1-2 I-Check<br>• Investigation 3 I-Check<br>• Survey/Posttest |
| **MS-PS4-3:** Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. | **Investigation 3** | • Investigation 4, Part 3 Notebook Entry<br>• Investigation 4 I-Check<br>• Survey/Posttest |
| **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. | **Investigation 2** | • Investigation 2, Part 3 Performance Assessment<br>• Investigation 1-2 I-Check<br>• Survey/Posttest |
| **MS-ETS1-2:** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. | **Investigation 2** | • Investigation 2, Part 3 Performance Assessment<br>• Investigation 1-2 I-Check<br>• Survey/Posttest |
| **MS-ETS1-3:** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. | **Investigation 2** | • Investigation 2, Part 3 Performance Assessment<br>• Investigation 1-2 I-Check<br>• Survey/Posttest |
| **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. | **Investigation 2** | • Investigation 2, Part 3 Performance Assessment<br>• Investigation 1-2 I-Check<br>• Survey/Posttest |

# Waves Investigations

## Investigation 1: Make Waves

Part 1: Pulse Rate
Part 2: Spring Waves

## Investigation 2: Wave Energy

Part 1: Energy in Waves
Part 2: Bridge Collapse
Part 3: Energy in Sound Waves

## Investigation 3: Light Waves

Part 1: Mirrors
Part 2: Spectra
Part 3: Color
Part 4: Refraction

## Investigation 4: Communication Waves

Part 1: Optical Fibers
Part 2: Sending Sound
Part 3: Sending Images



Start here to begin your review of the Grade 8 Waves Investigations Guide

## INTRODUCTION

By middle school, students have heard about waves but likely have had little science instruction on the topic. This is developmentally appropriate, because the fundamental characteristics that describe wave behavior and properties are described in terms of mathematical relationships and graphical models that are best suited for students in middle school. The anchor phenomenon for this course is energy transfer by waves.

This puts teachers of **FOSS Waves** in an exciting position, with the opportunity to delve into new content and challenge students to think about concepts they have never considered before. And the content of **FOSS Waves** is equally exciting to students as they manipulate springs and lasers to determine properties that eventually will be used to explain how their cell phones work. The classroom will be abuzz with excitement throughout this course.

The course proceeds from the most concrete observations, those of physical properties of mechanical waves, to the most abstract concepts, by which students develop a model of electromagnetic waves. Students will also delve into engineering applications and real-life connections along the way. Students leave this course with a greater appreciation and understanding of modern communications technology and a solid foundation for high school and college physics. The driving question for the course is how is energy transferred through waves?

**FOSS Waves** is a 6-week course.



Contents



**The NGSS Performance Expectations bundled 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

| | Investigation Summary | Time | Guiding and Focus Questions for Phenomena | Content and Disciplinary Core Ideas | Literacy/Technology | Assessment |
|---|---|---|---|---|---|---|
| Inv. 1 | **Make Waves**<br>Students measure their pulse under different circumstances to think about frequency. They create waves using metal springs. They use these simple waves to explore the fundamental properties of waves: wavelength, frequency, and amplitude. | **Activities**<br>**5 sessions** *<br>**Assessment**<br>**1 session** | ***What are the properties of all waves?***<br>**Part 1** **Pulse Rate**, 1 session<br>**What is frequency?**<br>**Part 2** **Spring Waves**, 4 sessions<br>**What defines a wave?** | • A wave is a back-and-forth pattern of motion that transfers energy.<br>• Key features of waves are crests, troughs, and nodes.<br>• Waves can be described in terms of wavelength, frequency, and amplitude.<br>• If you know the frequency and wavelength, you can calculate the speed of a wave. | **Science Resources Book**<br>"Transverse and Compression Waves"<br>**Online Activity**<br>"Metronome" (optional)<br>**Video**<br>*Standing Wave* | **Benchmark Assessment**<br>*Entry-Level Survey*<br>**NGSS Performance Expectation**<br>MS-PS4-1 |
| Inv. 2 | **Wave Energy**<br>Students learn about wave energy and compare energy in waves with different properties. Students look at an engineering failure and consider the work engineers must do to achieve a successful design. They use these ideas to develop a chamber that can effectively block sound waves. | **Activities**<br>**8 sessions**<br>**Assessment**<br>**1–2 sessions** | ***How do mechanical waves interact with matter?***<br>**Part 1** **Energy in Waves**, 2 sessions<br>**What is the relationship between wave properties and wave energy?**<br>**Part 2** **Bridge Collapse**, 2 sessions<br>**How are engineering challenges solved?**<br>**Part 3** **Energy in Sound Waves**, 4 sessions<br>**What is the best way to insulate a recording studio from outside sounds?** | • A mechanical wave travels through a medium.<br>• The amplitude, frequency, and wavelength of a wave are related to the energy transferred by the wave.<br>• The frequency and wavelength of a wave are related.<br>• Planning, research, modeling, and testing can help engineers develop successful designs.<br>• A sound wave is a mechanical wave, so it requires a medium to travel.<br>• Waves interacting with media can be absorbed or reflected. | **Science Resources Book**<br>"Ocean Waves"<br>"Tsunamis!"<br>"The Tacoma Narrows Bridge Disaster"<br>"Engineering Design Process"<br>"Sound Waves"<br>"Acoustic Engineering"<br>**Online Activity**<br>"Oscilloscope"<br>**Videos**<br>*Big Waves*<br>*Tacoma Narrows Bridge Collapse 1*<br>*Tacoma Narrows Bridge Collapse 2*<br>*Soundproof Engineering* | **Benchmark Assessment**<br>*Investigations 1–2 I-Check*<br>**NGSS Performance Expectations**<br>MS-PS4-1<br>MS-PS4-2<br>MS-ETS1-1<br>MS-ETS1-2<br>MS-ETS1-3<br>MS-ETS1-4 |

* A class session is 45–50 minutes.

| | Investigation Summary | Time | Guiding and Focus Questions for Phenomena | Content and Disciplinary Core Ideas | Literacy/Technology | Assessment |
|---|---|---|---|---|---|---|
| Inv. 3 | **Light Waves**<br>Students explore properties of light waves. They start by using mirrors to explore reflection. Students use spectroscopes to analyze spectra of visible light and learn more about the electromagnetic spectrum. They use filters to change the spectrum of a light source and to learn about color. Finally, they determine how refraction changes the path of light rays as they travel between media. | **Activities**<br>**8 sessions** | ***How do electromagnetic waves interact with matter?***<br>**Part 1 Mirrors**, 2 sessions<br>**What happens when light waves interact with matter?**<br>**Part 2 Spectra**, 2 sessions<br>**What do spectra reveal about light?**<br>**Part 3 Color**, 2 sessions<br>**Student-generated question, e.g., What makes objects appear as different colors?**<br>**Part 4 Refraction**, 2 sessions<br>**What happens to light waves at the interface between different media?** | • A wave model can be used to explain the properties of light.<br>• Light travels in straight lines, except at the interface between transparent media where refraction occurs.<br>• The angle of reflection equals the angle of incidence.<br>• The electromagnetic spectrum extends beyond visible light.<br>• Different wavelengths of visible light are perceived as different colors.<br>• When light shines on an object, the light is reflected, absorbed, or transmitted through the object. | **Science Resources Book**<br>"Reflecting on Light"<br>"Electromagnetic Spectra"<br>"Electromagnetic Radiation and Human Health"<br>"Throw a Little Light on Sight!"<br>"Seismic Waves"<br>**Online Activity**<br>"Refraction" | **Benchmark Assessment**<br>*Investigation 3 I-Check*<br>**NGSS Performance Expectation**<br>MS-PS4-2 |
| Inv. 4 | **Communication Waves**<br>Students learn how information can be encoded and sent as digital waves to transfer large amounts of information efficiently over large distances. They test properties of fiber-optic cables to develop an understanding of how total internal reflection allows data transfer by light. Students learn how data is encoded and sent as modulated waves to a recipient for demodulation. Students create digital waves and develop an understanding of how digital waves enable modern communications. | **Active Inv.**<br>**7 sessions** | ***How can waves be used to transmit information over large distances?***<br>**Part 1 Optical Fibers**, 2 sessions<br>**What are some design constraints in fiber-optic communications?**<br>**Part 2 Sending Sound**, 2 sessions<br>**How is sound sent through radio waves?**<br>**Part 3 Sending Images**, 2 sessions<br>**How are images sent through radio waves?** | • Light can be transmitted long distances through optical fibers.<br>• Complex information like words, sound, and images must be encoded to be sent as light.<br>• Digital waves can have the same information as analog waves; digital waves can be improved by using smaller increments.<br>• Many modern communication devices use digitized signals (sent as waves) as a reliable way to encode and transmit information.<br>• Modern technology encodes information to improve transmission quality, reliability, and speed. | **Science Resources Book**<br>"Lasers"<br>"Digital Communication"<br>"Telecommunication: From Telegraph to Smartphone"<br>**Online Activity**<br>"Digitized Images"<br>**Video**<br>*Fiber Optics* | **Benchmark Assessment**<br>*Investigation 4 I-Check*<br>*Posttest*<br>**NGSS Performance Expectation**<br>MS-PS4-3 |

* A class session is 45–50 minutes.

# FOSS INSTRUCTIONAL DESIGN

FOSS is designed around active investigation that provides engagement with science concepts and science and engineering practices. Surrounding and supporting those firsthand investigations are a wide range of experiences that help build student understanding of core science concepts and deepen scientific habits of mind.

## The Elements of the FOSS Instructional Design


Each FOSS investigation follows a similar design to provide multiple exposures to science concepts. The design includes these pedagogies.

- Active investigation in collaborative groups: firsthand experiences with phenomena in the natural and designed worlds
- Recording in science notebooks to answer a focus question dealing with the scientific phenomenon under investigation
- Informational reading in *FOSS Science Resources* books
- Online activities to acquire data or information or to elaborate and extend the investigation
- Opportunities to apply knowledge to solve problems through the engineering design process or to address regional ecological issues
- Assessment to monitor progress and motivate student learning

In practice, these components are seamlessly integrated into a curriculum designed to maximize every student's opportunity to learn.

A **learning cycle** employs an instructional model based on a constructivist perspective that calls on students to be actively involved in their own learning. The model systematically describes both teacher and learner behaviors in a systematic approach to science instruction.

The most recent model employs a series of five phases of intellectual involvement known as the 5Es: engage, explore, explain, elaborate, and evaluate. The body of foundational knowledge that informs contemporary learning-cycle thinking has been incorporated seamlessly and invisibly into the FOSS curriculum design.

Engagement with real-world **phenomena** is at the heart of FOSS. In every part of every investigation, the central phenomenon is referenced implicitly in the focus question that guides instruction and frames the intellectual work. The focus question is a prominent part of each lesson and is called out for the teacher and student. The investigation Scientific and Historical Background section is organized by focus question—the teacher has the opportunity to read and reflect on the phenomenon in each part before preparing for the lesson. Students record the focus question in their science notebooks, and after exploring the phenomenon thoroughly, explain their thinking in words and drawings.

In science a phenomenon is a natural occurrence, circumstance, or structure that is perceptible by the senses—an observable reality. Scientific phenomena are not necessarily phenomenal (although they may be)—most of the time they are pretty mundane and well within the everyday experience. What FOSS does to enact an effective engagement with the NGSS is thoughtful selection of phenomena for students to investigate.

**NOTE**
The anchor phenomena establish the storyline for the course. The investigative phenomena guide each investigation part. Related examples of everyday phenomena are incorporated into the readings, videos, discussions, formative assessments, outdoor experiences, and extensions.

## Active Investigation

Active investigation is a master pedagogy. Embedded within active learning are a number of pedagogical elements and practices that keep active investigation vigorous and productive. The enterprise of active investigation includes

- context: questioning and planning;
- activity: doing and observing;
- data management: recording, organizing, and processing;
- analysis: discussing and writing explanations.

***Context: questioning and planning.*** Active investigation requires focus. The context of an inquiry can be established with a focus question about a phenomenon or challenge from you, or in some cases, from students—What defines a wave? At other times, students are asked to plan a method for investigation. This might include determining the important data to gather and the necessary tools. In either case, the field available for thought and interaction is limited. This clarification of context and purpose results in a more productive investigation.

***Activity: doing and observing.*** In the practice of science, scientists put things together and take things apart, they observe systems and interactions, and they conduct experiments. This is the core of science—active, firsthand experience with objects, organisms, materials, and systems in the natural world. In FOSS, students engage in the same processes. Students often conduct investigations in collaborative groups of four, with each student taking a role to contribute to the effort.

The active investigations in FOSS are cohesive, and build on each other and the readings to lead students to a comprehensive understanding of concepts. Through the investigations, students gather meaningful data.

Online activities throughout the course provide students with opportunities to collect data, manipulate variables, and explore models and simulations beyond what can be done in the classroom. Seamless integration of the online activities forms an integral part of students' active investigations in FOSS.

***Data management: recording, organizing, and processing.*** Data accrue from observation, both direct (through the senses) and indirect (mediated by instrumentation). Data are the raw material from which scientific knowledge and meaning are synthesized. During and after work with materials, students record data in their notebooks. Data recording is the first of several kinds of student writing.

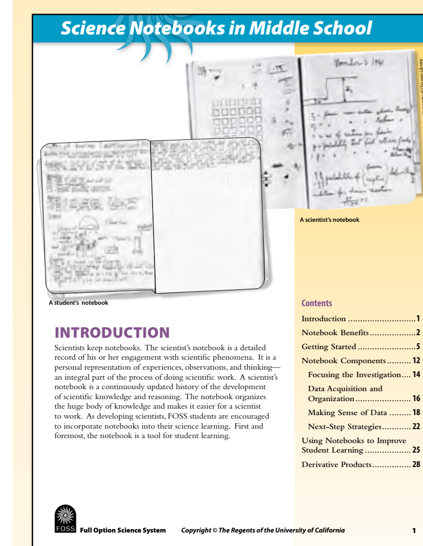
Students then organize data so that they will be easier to think about. Tables allow efficient comparison. Organizing data in a sequence (time) or series (size) can reveal patterns. Students process some data into graphs, providing visual display of numerical data. They also organize data and process them in the science notebook.

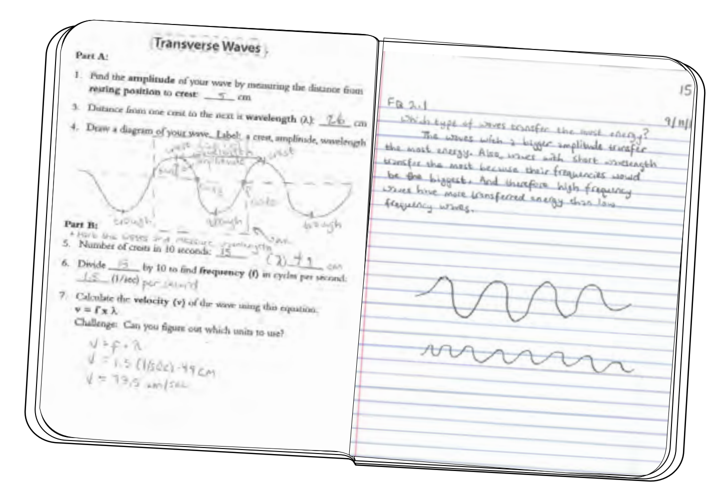
***Analysis: discussing and writing explanations.*** The most important part of an active investigation is extracting its meaning. This constructive process involves logic, discourse, and existing knowledge. Students share their explanations for phenomena, using evidence generated during the investigation to support their ideas. They conclude the active investigation by writing in their notebooks a summary of their learning as well as questions raised during the activity.

## Science Notebooks

Research and best practice have led us to place more emphasis on the student science notebook. Keeping a notebook helps students organize their observations and data, process their data, and maintain a record of their learning for future reference. The process of writing about their science experiences and communicating their thinking is a powerful learning device for students. And the student notebook entries stand as a credible and useful expression of learning. The artifacts in the notebooks form one of the core elements of the assessment system.

You will find the duplication masters for middle school presented in a notebook format. They are reduced in size (two copies to a standard sheet) for placement (glue or tape) in a bound composition book. Student work is entered partly in spaces provided on the notebook sheets and partly on adjacent blank sheets. Full-sized masters that can be filled in electronically and are suitable for projection are available on FOSSweb. Look to the chapter in *Teacher Resources* called Science Notebooks in Middle School for more details on how to use notebooks with FOSS.



# Waves Evaluation Checklist

**When prescreening FOSS Next Generation Waves for the four criteria below, use the references and page numbers provided to locate evidence.**

☐ **How does FOSS organize the learning around phenomenon and problems?**
FOSS Middle School courses are designed around culminating experiences and a driving question that support the progression of learning throughout the course. The driving question for this course is how is energy transferred through waves? Students leave this course with a greater appreciation and understanding of modern communications technology and a solid foundation for high school physics.

- Waves Grade 8 Course Map, page 8
- Waves Overview, pages 16-19

☐ **With FOSS, how are learning opportunities sequenced that enables students to make sense of the phenomenon or problems?**
FOSS investigations are grounded in storylines that are supported by a carefully designed progression of experiences. These experiences enable students to build on prior knowledge, ask questions, investigate, and make sense of core ideas over time.

- Waves Grade 8 Course Map, page 8
- Waves Overview Course Matrix, pages 12-15

☐ **What is the path of student thinking from their prior knowledge to the expected 3-dimensional learning outcomes when using FOSS?**
Students build on their prior knowledge through a multimodal learning cycle (see page 16 of this booklet) that provides them with opportunities to learn new information, make sense of and integrate new learning, and reflect and communicate their new understanding.

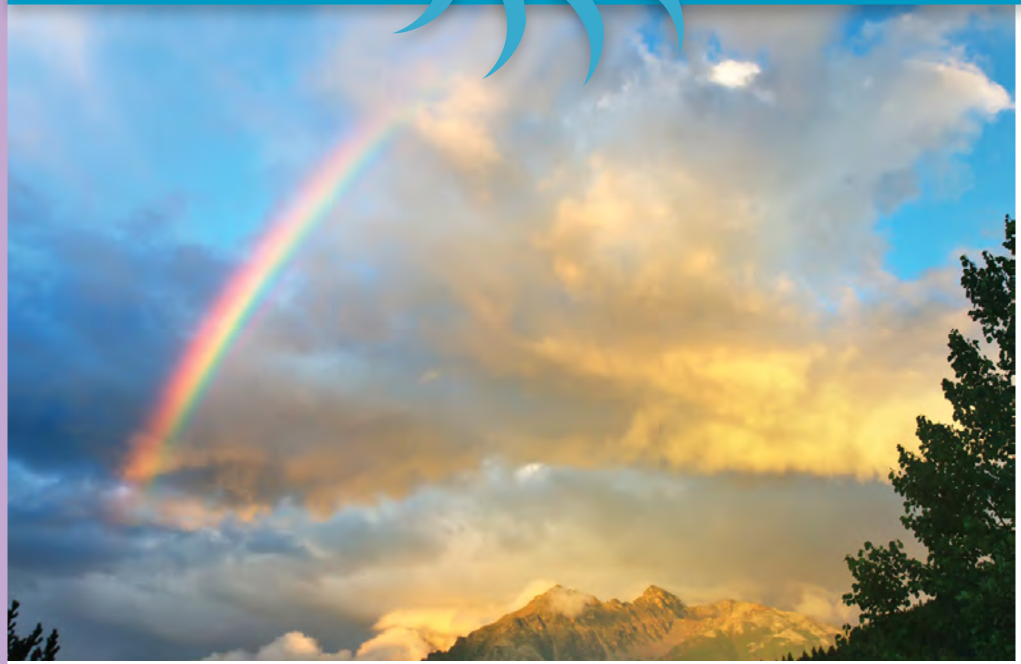
- Review light waves (activate prior knowledge), pages 29-30, steps 1-3
- Investigate by making observations and collecting data, pages 30-31, steps 4-7
- Make sense of observations using data, page 32, step 9-10
- Respond to the focus questions and construct an explanation, pages 32-33. Steps 11-12

☐ **How does FOSS help students show/demonstrate their 3-dimensional understanding of the phenomenon?**
FOSS uses a reflective-assessment cycle of performance, formative, and summative assessments, with Next Step Strategies interwoven into the instructional design.

- Assess progress: Performance assessment, page 31, Step 7
- Science Notebook entries, pages 32-33, steps 11 and 12
- Sample assessment items, pages 44-45



# INVESTIGATION 3 — *Light Waves*



**Part 1**
Mirrors

**Part 2**
Spectra

**Part 3**
Color

**Part 4**
Refraction

**Guiding question for phenomenon:**
***How do electromagnetic waves interact with matter?***

## PURPOSE

In *Light Waves*, students explore the phenomenon of light and properties of light waves. They start by using mirrors to explore reflection. Students then use spectroscopes to analyze spectra of visible light and learn more about the electromagnetic spectrum. They use filters to change the spectra of a light source and to learn about color. Finally, they determine how refraction changes the path of light rays as they travel between media.

### Content

- A wave model can be used to explain the properties of light.
- Light travels in straight lines, except at the interface between transparent media where refraction occurs.
- The angle of reflection equals the angle of incidence.
- The electromagnetic spectrum extends beyond visible light.
- Different wavelengths of visible light are perceived as different colors.
- When light shines on an object, the light is reflected, absorbed, or transmitted through the object.

### Practices

- Use lasers to carry out investigations of optical properties of different media.
- Use light spectra to identify light sources, and collect evidence to support light-wave explanations about color.

**Science and Engineering Practices**

- 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

**Disciplinary Core Ideas**

**PS4: How are waves used to transfer energy and information?**

PS4.A: Wave properties

PS4.B: Electromagnetic radiation

**Crosscutting Concepts**

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter

| | Investigation Summary | Time | Focus Question for Phenomenon, Practices | Content Related to DCIs | Literacy/Technology | Assessment |
|---|---|---|---|---|---|---|
| PART 1 | **Mirrors**<br>Students develop a model of waves to explain properties of electromagnetic radiation. They use lasers and mirrors to explore properties of light-wave reflection. | **Active Inv.**<br>2 Sessions * | **What happens when light waves interact with matter?**<br><br>**Practices**<br>Asking questions<br>Planning and carrying out investigations<br>Analyzing and interpreting data<br>Obtaining, evaluating, and communicating information | • A wave model can be used to explain the properties of light.<br>• Light travels in straight lines, except at the interface between transparent media where refraction occurs.<br>• The angle of reflection equals the angle of incidence. | **Science Notebook Entry**<br>Answer the focus question<br>**Science Resources Book**<br>"Reflecting on Light" | **Embedded Assessment**<br>Science notebook entry |
| PART 2 | **Spectra**<br>Students use spectroscopes to analyze spectra from various light sources and to observe that filters absorb light of specific wavelengths. They learn about the electromagnetic spectrum beyond the visible range. | **Active Inv.**<br>2 Sessions | **What do spectra reveal about light?**<br><br>**Practices**<br>Developing and using models<br>Planning and carrying out investigations<br>Analyzing and interpreting data<br>Constructing explanations<br>Obtaining, evaluating, and communicating information | • The electromagnetic spectrum extends beyond visible light.<br>• Different wavelengths of visible light are perceived as different colors.<br>• When light shines on an object, the light is reflected, absorbed, or transmitted through the object. | **Science Notebook Entry**<br>*Spectra Diagrams*<br>**Science Resources Book**<br>"Electromagnetic Spectra"<br>"Electromagnetic Radiation and Human Health" | **Embedded Assessment**<br>Science notebook entry |
| PART 3 | **Color**<br>Students use color filters to make inferences about the relationship between wavelengths of light and the color of objects. They use this understanding to create a color camouflage drawing. | **Active Inv.**<br>2 Sessions | **Student-generated question, e.g., What makes objects appear as different colors?**<br><br>**Practices**<br>Developing and using models<br>Planning and carrying out investigations<br>Analyzing and interpreting data<br>Constructing explanations | • Different wavelengths of visible light are perceived as different colors.<br>• When light shines on an object, the light is reflected, absorbed, or transmitted through the object. | **Science Notebook Entry**<br>*How Do We See?*<br>*Color Reflection Observations*<br>**Science Resources Book**<br>"Throw a Little Light on Sight!" | **Embedded Assessment**<br>Response sheet |
| PART 4 | **Refraction**<br>Students use lasers to determine that light can bend at the interface between two different media. They learn that when light bends so much that there is no refracted beam, there is total internal reflection. | **Active Inv.**<br>2 Sessions<br>**Assessment**<br>1–2 Sessions | **What happens to light waves at the interface between different media?**<br><br>**Practices**<br>Asking questions<br>Planning and carrying out investigations<br>Analyzing and interpreting data<br>Obtaining, evaluating, and communicating information | • Light travels in straight lines, except at the interface between transparent media where refraction occurs. | **Science Notebook Entry**<br>*Refraction Test*<br>**Science Resources Book**<br>"Seismic Waves"<br>**Online Activity**<br>"Refraction" | **Embedded Assessment**<br>Performance assessment<br>**Benchmark Assessment**<br>*Investigation 3 I-Check*<br>**NGSS Performance Expectation addressed in this investigation**<br>MS-PS4-2 |

* A class session is 45–50 minutes.

Pointed at a continuous-spectrum light source like the Sun or incandescent light, the spectroscope shows what wavelengths of light the human eye can see—about 400 to 700 nanometers (or 0.4 to 0.7 micrometers). Wavelengths of light are usually expressed in nanometers; a nanometer is a billionth of a meter, or a millionth of a millimeter. Visible light is just a small portion of the **electromagnetic spectrum**. These waves of electricity and magnetism range from giant wavelengths the size of buildings (radio waves) to tiny wavelengths the size of atomic nuclei (gamma rays).

In this course, students will only consider *emission* spectra—the light emitted by a radiant source. However, astronomers and physicists gain valuable data by considering *absorption* spectra, which displays wavelengths absorbed as light passes through a medium. For example, the Sun's absorption spectrum represents absorption of light by elements in the sun's atmosphere against the bright solar disk. About 100,000 absorption lines have been identified in the solar spectrum, improving the spectrum's ability to act as a unique identifier.

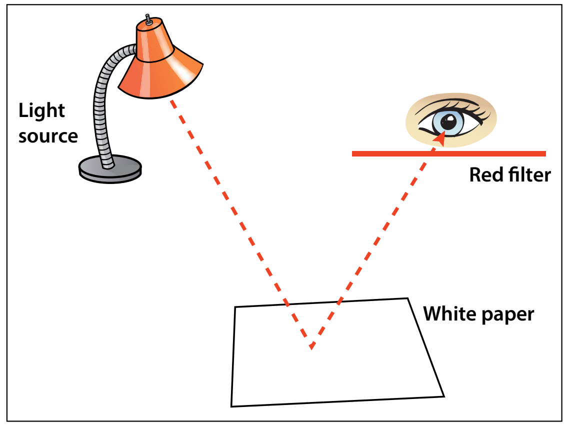
*"Our vision relies on reflected light, and color depends on what light is absorbed and reflected."*

## What Makes Objects Appear as Different Colors?

The color of an object is a result of the colors of light that reflect from the object. The colors of light that do not reflect from the object are absorbed in the object.

What does it mean for a light wave to be absorbed? The energy transmitted by the wave transfers to the object. It may be in the form of thermal energy, as when you sit in the sunlight and your skin warms. It may also be in the form of vibrational energy, which relates to how atoms and molecules move in place.

The concept of light being absorbed or reflected by an object is not intuitive. A blue shirt does not appear blue because it has the quality of blueness. It appears blue only when blue wavelengths of light reflect from the shirt to your eye. Any other wavelengths of light that shine on the shirt are absorbed by the shirt's fabric. Simple evidence that reflected blue wavelengths are what make the shirt appear blue can be observed by turning off the light in the room. With no light source, light doesn't reflect off the shirt, and the color of the shirt is indiscernible. And if the room is completely dark, you won't be able to see the shirt at all. Our vision relies on reflected light, and color depends on what light is absorbed and reflected.




How do color **filters** affect light waves? Looking at a white bulb through a red filter, we can see red. Only red wavelengths of light can pass through the filter. All other wavelengths are absorbed.

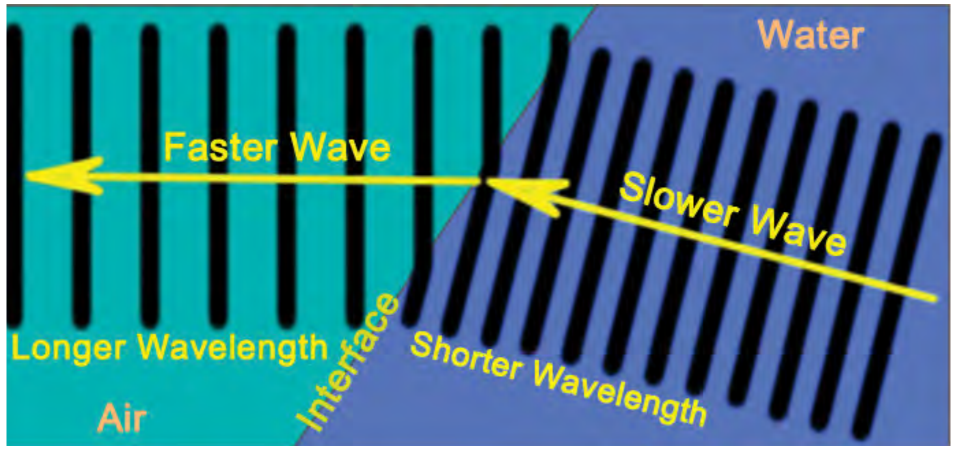


## What Happens to Light Waves at the Interface Between Different Media?

Light traveling through empty space is the fastest thing in the universe, going about 300,000 kilometers per second. It can also go through transparent and translucent media such as clear water, glass, and plastic. When light passes through these materials, however, it slows down a bit, giving rise to a very interesting phenomenon, refraction. Refraction is responsible for the behavior of light passing through lenses in telescopes and microscopes, as well as the creation of rainbows by prisms and water droplets.

A laser beam changes speed and direction when passing from one transparent medium into another, such as air into water. At the **interface** of these media, the light beam appears to bend at that location. That bend is refraction. The angle of refraction increases as the angle of incidence increases.

*"The beam direction bends toward the normal line when going from air into water, and away from it when going from water into air."*




**This diagram shows the change of speed and resultant change of angle as a light wave passes from one medium to another.**

One other detail may be noticed by keen observers: when the beam goes from water into air as opposed to air into water, the light beam's angle changes in the opposite direction. The beam direction bends toward the normal line when going from air into water, and away from it when going from water into air. The mathematical relationship that describes this behavior of light is Snell's law:

$$n_i \times \sin\theta_i = n_r \times \sin\theta_r, \quad \text{or} \quad \sin\theta_i = (n_r/n_i)\sin\theta_r,$$

where

$\theta_i$ = angle of incidence;

$n_i$ = index of refraction for the incident medium, a constant;

$\theta_r$ = angle of refraction; and

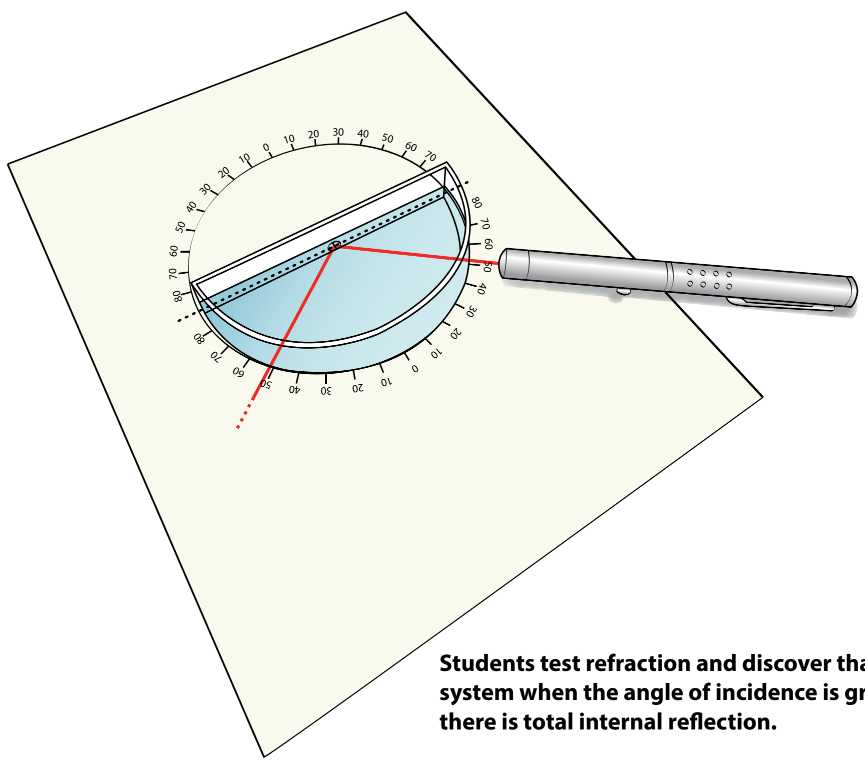
$n_r$ = index of refraction of the refracted medium, also a constant.

The angle of refraction depends on the nature of the two media and the change in speed of light that occurs at the interface. The index of refraction of a vacuum is 1. The index of refraction of air is very nearly 1 (1.000293). The index of refraction of water is 1.33.

So for light going from air into water, $(n_r/n_i) \approx 1.33$, which is greater than 1. That means that the angle of incidence is greater than the angle of refraction. For the reverse, when the beam goes from water into air, $(n_r/n_i) \approx 0.75$ (= 1/1.33). Since that is less than 1, the angle of incidence is less than the angle of refraction.

There is one other essential observation that students will make, using lasers and a refraction dish. When the angle of incidence is high enough, the angle of refraction is so great that the laser beam will not leave the dish. The beam bends so far that it is reflected within the dish. This is called **total internal reflection**. The principle of total internal reflection is essential for modern communication fibers.

*"The angle of refraction depends on the nature of the two media and the change in speed of light that occurs at the interface."*



**Students test refraction and discover that in this system when the angle of incidence is greater than 50°, there is total internal reflection.**





# MATERIALS *for*
## Part 4: *Refraction*

### Provided equipment

**For each student**

- 1 *FOSS Science Resources: Waves*
  - "Seismic Waves"

**For each group**

- 1 Cup, plastic
- 1 Refraction dish
- 1 Laser

**For the class**

- 1 Dropper

### Teacher-supplied items

**For each group**

- 1 Pen or pencil
- • Clear-plastic sheet protector

**For the class**

- • Chart paper
- • Water
- • Milk, 30-mL per class
- • Pitcher

### FOSSweb resources

**For each student**

- 1 Notebook sheet 20, *Refraction Test*
- 1 *Investigation 3 I-Check*

**For each group**

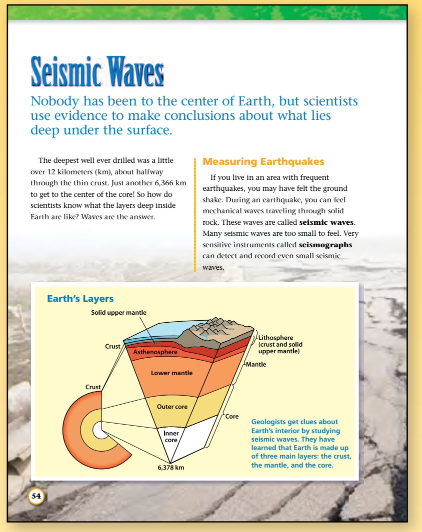
- 1 Teacher master L, *Protractor*

**For the class**

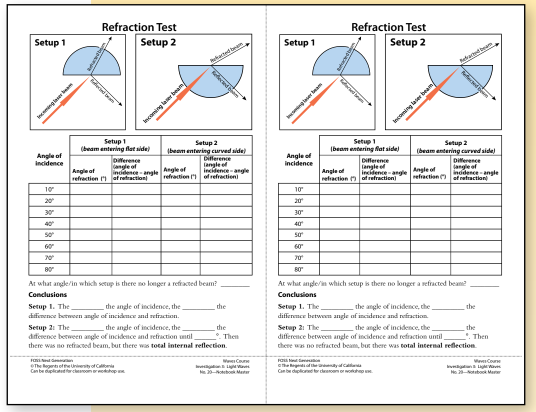
- • Online activity, "Refraction"
- • Teacher master P, *Refraction Test Instructions*

**For the teacher**

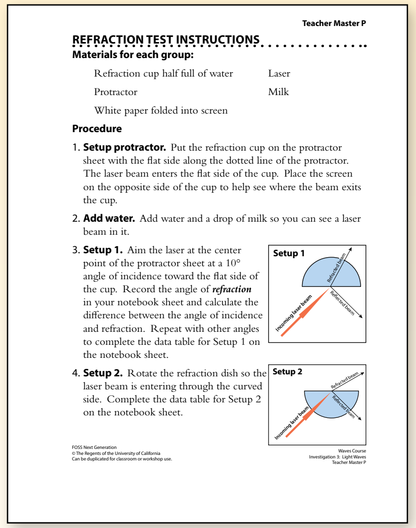
- 1 *Performance Assessment Checklist*
- 1 *Assessment Record*
- • Teaching slides, 3.4



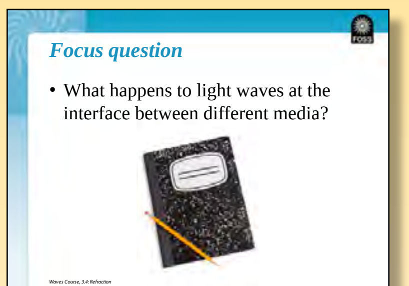

*FOSS Science Resources*




*No. 20—Notebook Master*




*Teacher Master P*




*Teaching slides, 3.4*

**SAFETY NOTE**
If any students have a dairy allergy, you can skip the milk. Results will be less striking, but still observable. Remind all students that there is no eating or drinking in science class.

# GETTING READY *for*

## Part 4: *Refraction*

**Quick Start**

| | |
|---|---|
| **Schedule** | 1 session active investigation<br>1 session wrap-up and review<br>1–2 sessions benchmark assessment |
| **Preview** | • Preview the FOSSweb Resources by Investigation for this part (such as printable masters, teaching slides, and multimedia)<br>• Test the online activity: "Refraction," Step 8<br>• Plan for homework: Steps 14, 16 |
| **Print or Copy** | **For each student**<br>• Notebook sheet 20<br>• *Investigation 3 I-Check,* or schedule it on FOSSmap<br>**For the teacher**<br>• *Performance Assessment Checklist*<br>• *Assessment Record* |
| **Prepare Material** | • Test refraction A |
| **Plan for Assessment** | • Review Step 7, "What to Look For" in the performance assessment<br>• Plan for benchmark assessment, Step 15, *Investigation 3 I-Check* |

### Preparation Details

**A Test refraction**

If you have never performed the class activity before, follow the instructions on teacher master P to set up a dish. Use just one drop of milk in a dish. Test each angle, as on notebook sheet 20. This will give you a sense of what students will observe and how to recognize whether groups are recording significant errors in their data.





# GUIDING *the Investigation*

## Part 4: *Refraction*

**SESSION 1**

**Students will...**
- Start to think about what happens to light at the interface between media (Steps 1–4)
- Test refraction by shining a laser through different transparent media (Steps 5–7)
- Extend investigation with homework (Step 8)

**SESSION 2**

**Students will...**
- Discuss observations and patterns, then learn about total internal reflection to explain the discrepant event (Step 9)
- Review vocabulary and answer the focus question (Steps 10, 11)
- Add additional information to the focus question from Part 1 and answer the guiding question (Step 12)
- Record key points from the investigation (Step 13)
- Extend investigation with homework (Step 14)

**SESSIONS 3–4**

**Students will...**
- Demonstrate understanding by responding to *Investigation 3 I-Check* (Step 15)
- Extend investigation with homework (Step 16)
- Review I-Check items through next-step strategies (Step 17)

**FOCUS QUESTION**

***What happens to light waves at the interface between different media?***

**SESSION 1** *45–50 minutes*

### 1. Review light waves

Ask,

➤ *What is the difference between mechanical waves and electromagnetic waves?* [Mechanical waves have to travel through a medium; electromagnetic waves can travel through a medium or empty space.]

➤ *What media have we seen electromagnetic waves pass through?* [Air, glass (windows, bulbs), plastic (filters).]

**EL NOTE**

***Refer to the waves tree map (from Part 1 of this investigation) and add any new information.***

**EL NOTE**

***Make a diagram on the word wall and label with the word "interface".***

**TEACHING NOTE**

*Students often identify the cup's plastic as a medium through which light waves shine. You can confirm this is part of the system, and that they will be measuring refraction as light travels from one part of the system (water and plastic) to another part of the system (air).*

**EL NOTE**

***Add "refraction" to the diagram on the word wall.***

**SCIENCE AND ENGINEERING PRACTICES**

Planning and carrying out investigations

### 2. Test water

Distribute a plastic cup with water in it to each table. Ask students to place a pen or pencil in the cup and observe closely, then invite groups to share their observations. Students will report that if you look closely at the top of the water, the pencil appears to be broken or bent. Ask,

➤ *Why does the pencil appear to be bent through the water?*

Tell students that the area where two media meet, in this case air and water, is called the **interface**. In this session, students will do some experiments that will show exactly how light bends at the surface of the water.

### 3. Focus question: What happens to light waves at the interface between different media?

Ask students to turn to the next clean page in their notebooks and write the focus question. They should leave space under the question to answer it later.

➤ *What happens to light waves at the interface between different media?*

### 4. Introduce *refraction* and develop procedure

Ask students to look at the "bent" pencil. Ask,

➤ *Through what media interface do light waves travel to make the pencil look bent?* [Water and air.]

Tell students that when light waves change direction as they move between media, it is called **refraction**. In this case, light waves bend when they travel between water and air.

Ask students to think about and discuss how they might set up a procedure to observe and measure when shining beams of light through water and air. Encourage students to think about the pencil, cup, and water, and to refer back to the investigation of angles they did in Part 1. Students may suggest ideas such as shining the laser into the cup at different angles to check for refraction, using the protractor from Part 1. Give students time to build off other students' ideas to work toward a working procedure.

### 5. Prepare for experimentation

Hold up a refraction dish and point out the curved side and flat side. Tell students,

*This dish fits precisely on the protractor you used in Part 1. Using the dish and protractor will allow you to test refraction by shining a laser toward the water at precise angles.*

Project teacher master P, *Refraction Test Instructions*, and distribute a copy of notebook sheet 20, *Refraction Test*, to each student. Walk students through the procedure and data collection.

Highlight the "Setup 1" diagram and discuss how to collect data and calculate the difference between angle of incidence and angle of refraction. The angle of refraction will be measured as the distance between the refracted beam and the normal line.

Highlight the "Setup 2" diagram and make sure students understand how to move the refraction dish and laser to collect data.

### 6. Conduct refraction test

Give students time to carry out the activity. Circulate and look for groups who may be confused about the setup, how to measure the angle of refraction, or how to calculate the difference between the angle of incidence and angle of refraction.

As students work with Setup 2, they may be perplexed when they cannot find an angle of refraction (around 50 degrees). As you circulate among groups, encourage students to discuss what may be causing that. Suggest that if they cannot find a refracted beam, they will be able to answer the question below the data table.

### 7. Assess progress: performance assessment

As students set up their tests, listen to the group discussions and observe how students work together to assess students' three-dimensional learning. Note student progress on the *Performance Assessment Checklist*.

**What to Look For**

- *Students conduct the investigation and collect data, then look for patterns in the data. (Planning and carrying out investigations; analyzing and interpreting data; PS4.A: Wave properties; patterns.)*
- *Students witness a discrepant event when they cannot find an angle of refraction, and ask questions about what may be causing this anomaly in the data. (Asking questions; analyzing and interpreting data; PS4.B: Electromagnetic radiation; patterns.)*
- *Students share ideas with each other about what may be causing the anomalous data when they cannot find an angle of refraction. (Obtaining, evaluating, and communicating information; PS4.A: Wave properties; PS4.B: Electromagnetic radiation.)*

**MATH CONNECTION**

*This supports Common Core State Standards for Math 8.G 1.*

**SCIENCE AND ENGINEERING PRACTICES**

Using mathematics and computational thinking

**SCIENCE AND ENGINEERING PRACTICES**

Asking questions

Planning and carrying out investigations

Analyzing and interpreting data

Obtaining, evaluating, and communicating information

**DISCIPLINARY CORE IDEAS**

PS4.A: Wave properties

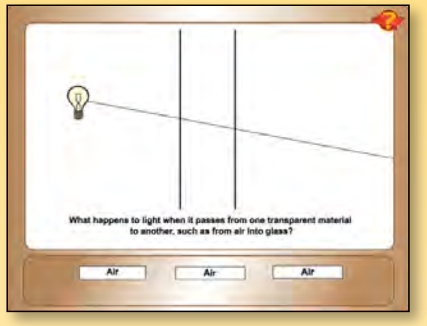
PS4.B: Electromagnetic radiation

**CROSSCUTTING CONCEPTS**

Patterns

## 8. Extend the investigation with homework

Students can extend their classroom investigation by using the online activity "Refraction." Students should perform 10–15 tests, record their data in a data table that they design, and write a concluding statement that summarizes their findings.




**SESSION 2** *45–50 minutes*

## 9. Draw conclusions

Have students take a few minutes to compare notes about their findings in Session 1. Call on students to share observations and inferences in a class discussion. Encourage them to cite patterns they notice in their data and the cause-and-effect statements they made based on those patterns. If needed, guide the discussion with these questions and prompts.

➤ *What pattern did you notice happening to the laser light beam at the higher angles of incidence?* [It bends more at greater angles.]

Draw students' attention to the conclusion section of notebook sheet 20, and ask for students to determine the relationship between incidence and refraction.

➤ *Setup 1: The _________ the angle of incidence, the _________ the difference between angle of incidence and refraction.* [Greater, greater.]

➤ *Setup 2: The _________ the angle of incidence, the _________ the difference between angle of incidence and refraction until _____.* [Greater, greater, about 50 degrees.]

Tell students that when the light is refracted so much that it will not exit the medium (the water in the dish), that is called **total internal reflection**.

**CROSSCUTTING CONCEPTS**

Patterns

Cause and effect

## 10. Review vocabulary

Give students a few moments to review the vocabulary developed in this investigation and to update their vocabulary indexes if they haven't already done so. Suggest that students make diagrams to illustrate each of these new terms.

*interface*
*refraction*
*total internal reflection*

## 11. Answer the focus question

Ask students to return to the focus question. Have students respond to the focus question with any information they've learned.

➤ *What happens to light waves at the interface between different media?*

When students are done, have a few share their responses. Other students can draw a line of learning under their own response and add new information.

**EL NOTE**

***For students who need scaffolding for the focus question, give them a few minutes to discuss the question, the procedure, and the results with a partner before writing. You can provide sentence frames such as:***
***We were trying to find out _____.***
***We experimented with_____.***
***These data suggest that _____.***
***I'm wondering if_____.***



## 12. Answer the guiding question

Ask students to review the focus question from Part 1 in their notebooks.

➤ *What happens when light waves interact with matter?*

Ask students to review what they wrote in Parts 1 and 3. They will now synthesize their previous response with new information to answer the guiding question.

➤ *How do electromagnetic waves interact with matter?*

Remind students to include information from the entire investigation in their response. Encourage students to be reflective in their writing. If needed, provided prompts such as:

I used to think _____. Now I think _____.

My thinking about _____ has changed because _____.

I learned that _____. I'm still wondering about _____.

From the reading I learned that _____.

New questions I have are _____.

You might have students use images from the *FOSS Science Resources* book, such the image on pages 32–33, to connect their thinking to the real world. Students can also ask additional questions about light and electromagnetic spectrum.

**SCIENCE AND ENGINEERING PRACTICES**

Developing and using models
Analyzing and interpreting data
Constructing explanations

**DISCIPLINARY CORE IDEAS**

PS4.A: Wave properties
PS4.B: Electromagnetic radiation

**CROSSCUTTING CONCEPTS**

Patterns
Cause and effect
Systems and system models
Energy and matter

**SCIENCE AND ENGINEERING PRACTICES**

Asking questions

## WRAP-UP

### 13. Review notebook entries

Ask students to go through their notebook entries and select one key point that summarizes an important finding from this investigation. They should record this point in their notebooks.

Have students share their key point with their group, selecting one key point within the group to share with the class. Create a class chart of key points by recording each group's idea on a piece of chart paper, whiteboard, or document projected from the computer. You might need to help groups rephrase their key points for clarity.

Students should record the key points in their notebooks and reference the page numbers in their notebooks where additional information supports each key point. By using science and engineering practices and exploring core ideas through the lens of crosscutting concepts, students should come forward with these big ideas in the review discussions.

- Light is electromagnetic radiation that travels in straight lines as electromagnetic waves. (Developing and using models; PS4.A: Wave properties; PS4.B: Electromagnetic radiation; systems and system models; energy and matter.)
- Spectroscopes reveal that white light is composed of many colors, each of which has a distinct wavelength. (Analyzing and interpreting data; PS4.A: Wave properties; PS4.B: Electromagnetic radiation; patterns; energy and matter.)
- Reflection of all wavelengths of visible light makes an object appear white. Absorption of all wavelengths makes an object appear black. (Analyzing and interpreting data, constructing explanations; PS4.B: Electromagnetic radiation; cause and effect; energy and matter.)

### 14. Extend the investigation with homework

By now, students have answered many of the questions that they asked about light in Part 1. Give students a few moments to talk in their groups and see if there are any remaining questions. Decide whether you will answer these before the I-Check, or whether they are suitable for homework/online research by students, or will be covered in later investigations. See Extending the Investigation for more information and answers to common questions.





**SESSION 3** *45–50 minutes*

### 15. Assess progress: I-Check

Administer *Investigation 3 I-Check*, asking students to respond to the items on paper or online on FOSSmap. Students should independently answer the questions. When taking the I-Check, students should not use their notebooks, but the notebooks are a good tool to use when students later reflect on their answers.

## READING IN *Science Resources*

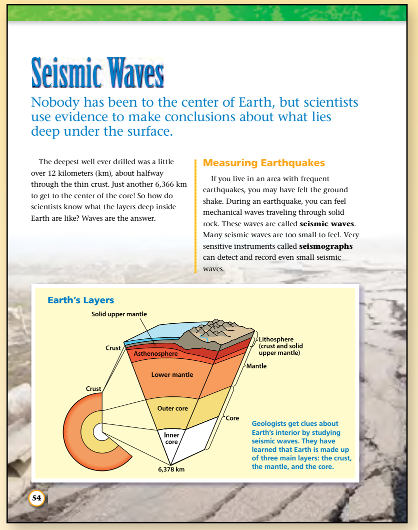
### 16. Extend the investigation with homework

The article "Seismic Waves" can be assigned as homework to extend ideas beyond the class discussion. It can also be assigned to students who finish the I-Check early.

Tell students that this article explains how seismic waves are used to find out what lies below Earth's surface. To support reading comprehension, suggest students follow this procedure:

a. Before reading, analyze the diagrams, and read the captions and subtitles. Set up your notebook to take three-column notes. See example. Start by writing down the Think Questions in the first column and a few more of your own. Write what you think you know about the questions in the second column.
b. As you read, jot down the information you obtain from the text in the third column of your notes page.
c. After reading, compare what you thought you knew to what you found out from the text. Reread any sections you had difficulties with and add any new questions to your list.

See the example on the next page.


Seismic Waves

Nobody has been to the center of Earth, but scientists use evidence to make conclusions about what lies deep under the surface.

The deepest well ever drilled was a little over 12 kilometers (km), about halfway through the thin crust. Just another 6,366 km to get to the center of the core! So how do scientists know what the layers deep inside Earth are like? Waves are the answer.

Measuring Earthquakes

If you live in an area with frequent earthquakes, you may have felt the ground shake. During an earthquake, you can feel mechanical waves traveling through solid rock. These waves are called **seismic waves**. Many seismic waves are too small to feel. Very sensitive instruments called **seismographs** can detect and record even small seismic waves.



Geologists get clues about Earth's interior by studying seismic waves. They have learned that Earth is made up of three main layers: the crust, the mantle, and the core.

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*FOSS Science Resources*

| Think Questions | I think I know | Answers |
|---|---|---|
| *How does refraction help geologists determine what is below the surface of Earth?* | | *Waves change speed and direction as they travel between materials, so measuring the refraction of underground waves gives you information about the materials underground.* |
| *How are waves used to pinpoint the center of an earthquake?* | | *When you time the arrival of earthquake waves to different locations, you can figure out where the earthquake occurred.* |
| *How would you use a seismograph to look at what is hidden in Earth?* | | *You could use a seismograph to figure out the speed and direction of different waves. If you combine information from various locations, you can infer what materials are under Earth's surface.* |

**SESSION 4** *45–50 minutes*

### 17. Discuss I-Check results

Code the I-Check items, but do not make any marks on student responses. Note that FOSSmap automatically codes most of the items and provides you with student and class reports. Coding guides can be found on FOSSweb. You can record student results on the Assessment Record or download spreadsheets from FOSSmap for recording. Note important points about the items to review with students.

Return the I-Checks to students. Use self-assessment strategies as described in the Assessment chapter for each item to facilitate reflection and clarify student thinking.

**ELA CONNECTION**

*These suggested strategies address the Common Core State Standards for ELA for literacy.*

*RST 1: Cite evidence to support analysis of science texts.*

*RST 2: Determine the central ideas or conclusions of a text; provide an accurate summary.*

*RST 7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.*

*WHST 9: Draw evidence from informational texts to support analysis, reflection, and research.*

**EL NOTE**

***Discuss the origin of the word, seismic. Explain that in ancient Greek, "seismos" meant an earthquake. Now, seismic refers to anything of or relating to earthquakes or other vibrations of the Earth and its crust.***

**TEACHING NOTE**

*During or after these next-steps with the I-Check, you might ask students to make choices for possible derivative products based on their notebooks for inclusion in a summative portfolio. See the Assessment chapter for more information about creating and evaluating portfolios.*





## EXTENDING *the Investigation*

- **Answer light questions**

  Here's a list of common questions that students ask about light prior to instruction. They are answered here for your convenience. Other questions could be researched by students online.

  - *How does light travel?* [Electric and magnetic waves.]
  - *What kind of wave model (transverse or compression) describes light?* [Transverse.]
  - *How are different colors created?* [By different wavelengths of light.]
  - *What kind of media can light waves travel through?* [No medium is required; they can pass through transparent or translucent media.]
  - *How far can light waves travel?* [Forever, in empty space.]
  - *How fast can light waves travel?* [300,000 km per second.]
  - *What units can you use to measure light waves?* [Wavelengths of light are typically measured in nanometers. A unit to measure light intensity is candela.]
  - *How many light waves does it take to harm you?* [Ultraviolet light can cause sunburn. X-rays and gamma rays can kill if intensity is great enough. See also the *FOSS Science Resources* article "Electromagnetic Radiation and Human Health."]

**TEACHING NOTE**

*Encourage students to use the Science and Engineering Careers Database on FOSSweb.*

Contents



**NOTE**
For the most up-to-date assessment masters, answer sheets, and coding guides, go to FOSSweb for this course.

# THE FOSS ASSESSMENT SYSTEM *for Middle School*

"Assessment is like science. …To assess our students, we plan and conduct investigations about student learning and then analyze and interpret data to develop models of what students are thinking. These models allow us to predict the effect of additional teaching, addressing the patterns we notice in student understanding and misunderstanding. Assessment allows us to improve our teaching practice over time, spiraling upward" (*2016 Science Framework for California Public Schools, Kindergarten through Grade 12,* chapter 9, page 3).

An important rule of thumb in educational assessment is that assessments should be designed to meet specific purposes. One size does not fit all. The FOSS assessment system provides ample opportunities for both formative and summative assessment. Formative assessments provide short-term information about learning by making students' thinking visible in order to guide instructional decisions. Summative assessments provide valid, reliable, and fair measures of students' progress over a longer period of time, at the end of a course, or the end of the year. The purpose for the assessment determines the choice of instruments that you will use.

The FOSS assessment system is designed to assess students in cycles: short, medium, and long. The assessment tasks allow students to demonstrate their facility with three-dimensional understanding of science.

**Short cycle. Embedded assessment** opportunities are incorporated into each part of every investigation. These assessments use student-generated artifacts, including science notebook entries, answers to focus questions, response sheets, and **performance assessments**. Embedded assessments provide daily monitoring of students' learning and practices to help you make decisions about next instructional steps. Embedded assessments using science notebooks provide evidence of students' overall conceptual development. Performance assessments focus on science and engineering practices, crosscutting concepts, and disciplinary core ideas.





**I-Check** opportunities occur at the end of one or two investigations. These assessments are hybrid tools that provide summative information about students' achievement, and have even more power when used for formative assessment. Daily embedded assessments provide a quick snapshot of students' immediate learning; I-Checks challenge students to put this learning into action in a broader context. Now students must think about the science and engineering practices, disciplinary core ideas, and crosscutting concepts they have been learning, and know when, where, and how to use them. I-Checks (short for "I check my own understanding") also provide opportunities for guided self-assessment, an important skill for future learning and development of a growth mindset. Properly executed feedback can help a student focus attention on areas that need strengthening. When a student responds to feedback, you can develop an even more precise understanding of the student's learning. A feedback/response dialogue can develop into a highly differentiated path of instruction tailored to the learning requirements of individual students.

**Medium and long cycle.** *Entry-Level Surveys*, *Posttests*, and portfolios are tools provided for medium- and long-cycle assessment. Students take the *Entry-Level Survey* before instruction begins. This entry-level assessment provides you with information about students' prior knowledge of disciplinary core ideas and science and engineering practices. What emerging conceptions do they have that you will be able to build upon as you move through the course? Students are encouraged to answer the questions as best they can, so you get the information you need to move instruction forward effectively.

The *Posttest* is given at the end of the course. It provides summative information about students' three-dimensional learning. It also lets students compare their *Entry-Level Survey* responses to those on the *Posttest* to see how their understanding has grown. You can also use the *Posttest* for formative instructional evaluation by making notes about things you might want to focus on or do differently next time you teach the course.

Students can also collect work samples in a portfolio as they work through the course. At the end of each investigation, they can create derivative products to document their three dimensional-learning.

See more about these assessments in the section "Benchmark Assessment."

**TEACHING NOTE**

*FOSS recommends that you do not grade notebook entries. This ensures a risk-free environment for students to write freely, knowing mistakes are part of learning. If you need to give a grade, have students complete a derivative product based on a notebook entry. Students might rewrite a focus-question answer, write up part of a lab, or revise a response sheet and turn it in, knowing that this product will be graded.*

# EMBEDDED *Assessment*

In FOSS middle school, the unit of instruction is the course—a sequence of conceptually related learning experiences that leads to a set of learning outcomes. A science notebook gives students a place to record their thinking and develop deeper understanding of the course content by articulating relationships, patterns, and conclusions, as well as by asking questions that will guide further exploration. Science notebook entries give both you and your students opportunities to review and reflect on students' thinking.

From the assessment point of view, a science notebook is a collection of student-generated artifacts that exhibit student learning. You can informally assess student skills, such as the ability to use charts to record data, while students are working with materials. At other times, you collect the notebooks and review them for insights or errors in conceptual understanding. The displays of data and analytical work provide a measure of the quality and quantity of student learning.

As you progress through the course, you will see different strategies used throughout the *Investigations Guide*. These will be marked with the notebook or assessment icon. As you try these strategies, note the positive effects that keeping notebooks have on students' work, as students continually practice expressing their conceptual development in writing. Embedded assessments help you better understand and address students' misconceptions.

## Assessment Opportunities

Notebook entries serve as assessment opportunities for learning. Each part of each investigation is driven by a **focus question**. Each part usually concludes with students writing or revising an answer to the focus question in their notebooks. Their answers reveal how well they have made sense of the investigation and whether they have focused on the relevant actions and discussions.

At times, students use prepared **notebook sheets** to help organize and think about data. You can note how carefully students are making and organizing observations and how they think about analyzing and interpreting the data. Sometimes students answer a specific question that provides additional insight into understanding. You will find answers for notebook sheets in the Notebook Answers chapter.



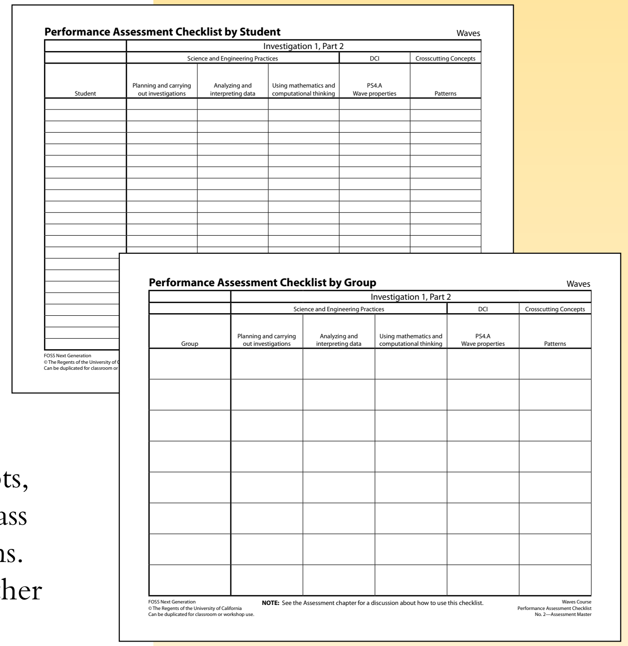


FOSS

**Response sheets** provide more formal embedded-assessment data. These are a specific kind of notebook sheet that assess specific scientific knowledge that students often struggle with, giving you an additional opportunity to help students untangle concepts that they may be overgeneralizing or have difficulty differentiating.

Students also generate **free-form notebook entries** that can be used for assessing progress. These may occur when you choose to have students organize their own data, or when events in the classroom suggest a new aspect of students' learning that you want to know more about.

The ***Entry-Level Survey*** and **quick writes** (or quick draws) present questions that students answer before instruction, so you can analyze their prior knowledge and misconceptions. Knowing students' intuitive ideas (or prior knowledge) will help you know what parts of the investigations need the most attention. Make sure students date their entries for later reference. Quick writes can be done on a quarter sheet of paper or an index card. You collect them, review them, and return them to students to affix into their notebooks for self-assessment later in the investigation.




**Performance assessments** occur at times in the course as a way to specifically check students' three-dimensional progress, checking science and engineering practices, crosscutting concepts, and disciplinary core ideas. These assessments happen during class as you circulate among student groups during their investigations. Sometimes you will simply watch what students are doing; at other times prompts or interview questions will be suggested.

## Time Management

In order to collect enough data from embedded assessments to adequately inform instruction, plan to spend 15 minutes after each part of an investigation is completed, reviewing student learning by examining student work. In middle school, you face the challenge of having a large number of students. This may mean collecting only a portion of students' notebooks at a time to keep your workload manageable. A sample of student notebooks across your classes should represent the general levels of conceptual understanding that students have. Some work, such as quick writes and notebook sheets, can first be completed on separate sheets of paper. These are easier to collect, read, and later return to students for their notebooks.

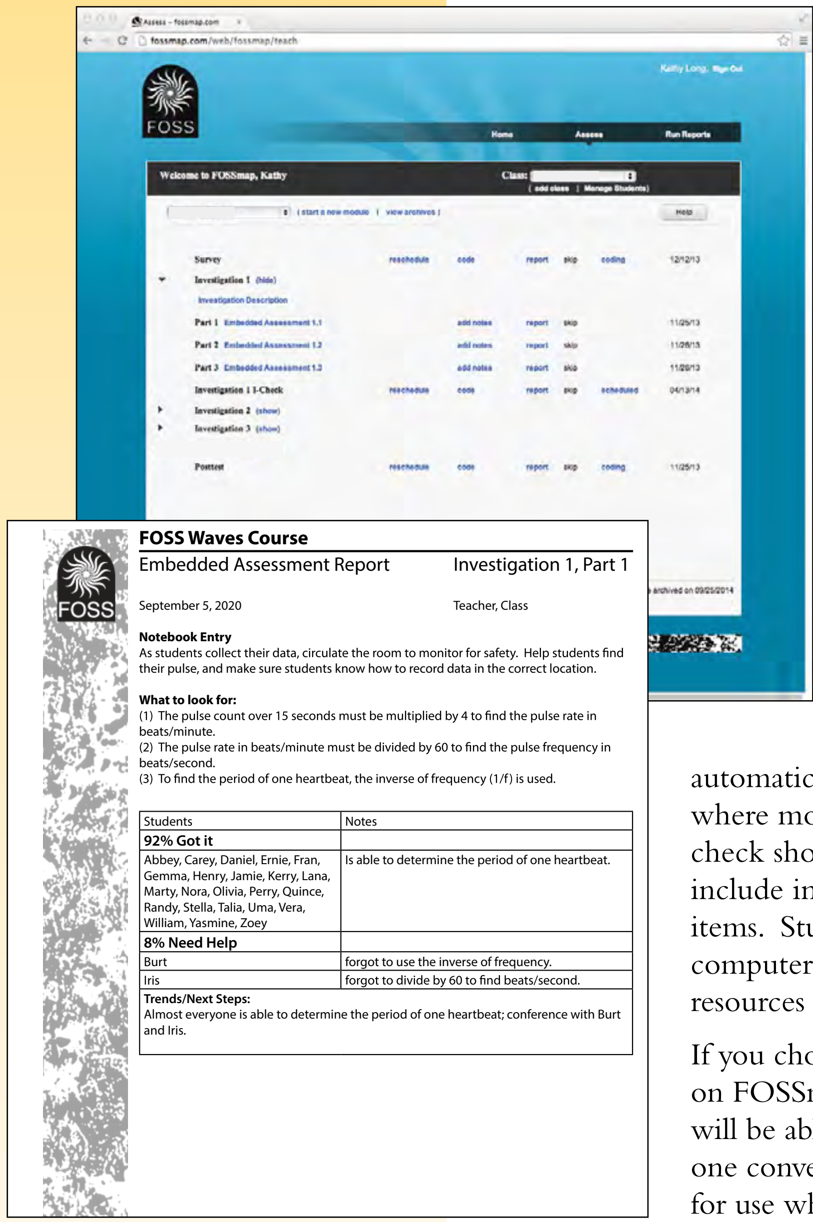
**NOTE**

You need only 15 minutes after an investigation part to review student work and gather evidence of learning. See the reflective-assessment practice later in this chapter.

# FOSSMAP *and Online Assessment*

**FOSSmap** (fossmap.com) is the assessment management program designed specifically for teachers using the FOSS Program in middle school. This user-friendly system allows you to open online assessments for students, to review codes for student responses, and to run reports to help you assess student learning. FOSSmap was developed at the Lawrence Hall of Science in conjunction with the Berkeley Evaluation and Assessment Research (BEAR) center at the University of California, as part of a 5-year research and development project funded by the National Science Foundation. It is based on the tools developed in the Assessing Science Knowledge (ASK) Project.

Navigation page and a sample Embedded Assessment Report




Embedded-assessment data can be entered into FOSSmap to provide evidence of differentiated instruction, to run reports for formative analysis, and to print notes to provide feedback in student notebooks. It is also a tool for teacher reflection and instructional improvement from year to year.

FOSSmap allows you to give students access to the **online assessment** system (fossmap.com/icheck). Students log in to this system to take the benchmark assessments (I-Checks and *Posttest*). Responses are automatically sent to the FOSSmap teacher program, where most are automatically coded. You will need to check short answers (mainly for correct answers that include inventive spelling), and to code open-response items. Students can answer open-response items on the computer or using paper and pencil, depending on the resources you have available.

If you choose to have students take the *Entry-Level Survey* on FOSSmap, the answers will not be coded, but you will be able to look at all of the students' responses in one convenient place, and make notes about each item for use when you teach the different parts of the course.

## FOSSmap Reports

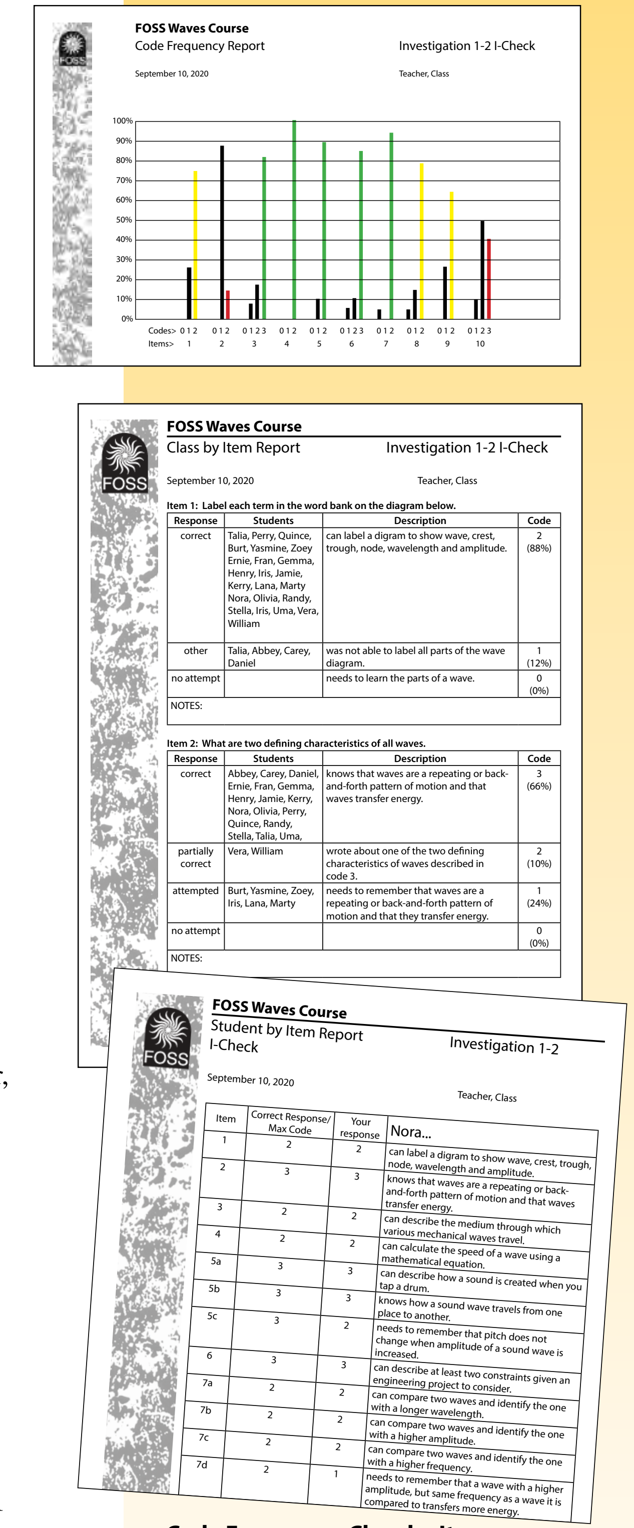
The **Code Frequency Report** tells you at a glance which items were problems for the class. Each bar on the report represents how many students received a particular code. The colored bars indicate how many students received the highest (max) code possible for the item. Green bars indicate that 70% or more students got the highest code. Yellow bars indicate that 51% to 69% of students got the highest code. Red bars indicate that 50% or fewer of the students got the highest code on that item. So the quick and easy way to use this report is to look for the red bars. The red-bar items are the ones you want to take back to students for self-assessment activities.

Run the **Class by Item Report** to get the details on each item, especially the "red bar" problem items from the Code Frequency Report. This report displays students' names for each response, with a brief description of what each code means in terms of full or partial understanding. The report helps you decide what steps need to be taken next.

The **Student Responses Report** provides a printout of individual students' responses to all items answered online (including open-response items if they were typed into the system). This report is useful for student self-assessment activities. You can project the items for class discussion, and students can make notes in their notebooks, add to, or revise answers based on the discussions during the self-assessment activities.

The **Student by Item Report** (a good report to send home to parents) lists all the items on a test and shows how individual students responded to each item. It also provides the correct answer, or max code, and a description of what the student knows or needs to work on, based on the evidence inferred from each item.

The **Class All Codes Report** provides a spreadsheet that can be opened in any spreadsheet program. It gives you a list of the students, the maximum code for each item and the code each student received on each item. You can use this sheet if you want to convert codes into scores in order to determine percentage correct if that is needed for giving grades. To do that, you need to subtract 1 from each code, so that you are not actually awarding a point for wrong answers. Remember though, that FOSS assessments are designed to be diagnostic and not minimum mastery, so you may need to adjust your cut points for giving ABC grades. For example, instead of 90% being an A, you may decide that 80% is a better cut point for an A.




Code Frequency, Class by Item, and Student by Item Reports

# SAMPLE ASSESSMENT ITEMS

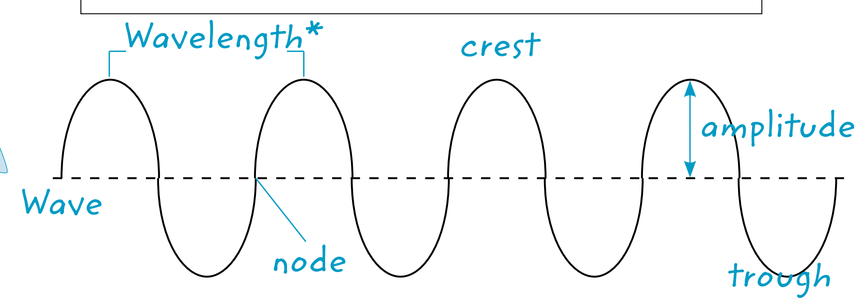
ANSWERS

## INVESTIGATIONS 1–2 I-CHECK

WAVES

1. Label each term in the word bank on the wave diagram below.

| **Word Bank** | wave | wavelength | amplitude |
|---|---|---|---|
| | crest | trough | node |




2. What are two defining characteristics of all waves (not included in the word bank above)?
   (1) A repeating or back-and-forth pattern of motion
   (2) Waves transfer energy.

3. For each mechanical wave, describe a medium through which it transmits.

| Wave | Medium |
|---|---|
| Spring | metal coil |
| Ocean | water |
| Sound | air |

4. A student measures the frequency of a wave as 2 waves/second, and the wavelength as 40 cm/wave. Use the velocity equation ($v = f \times \lambda$) to calculate the speed of the wave. Show your work and include units.

   v = 2 waves/second x 40 cm/wave
   v = 80 cm/second

FOSS Next Generation


Waves Course
Investigations 1–2 I-Check
Page 1 of 4

**TEACHING NOTE**

*Please note that wavelength can be measured from crest to crest, trough to trough, or node to node.*

**NOTE**

Look for these resources in the Assessment section in *Teacher Resources* on FOSSweb.

- Assessment chapter
- Assessment masters
- Coding guides
- Assessment charts





*Focus on Science and Engineering Practices*
*Focus on Disciplinary Core Ideas*
*Focus on Crosscutting Concepts*

### Item 1

This item provides evidence that students can label a model of a simple wave (structure and function).

| Code | If the student . . . |
|---|---|
| 2 | labels all correctly (see answer sheet). |
| 1 | labels any other way. |
| 0 | makes no attempt. |

**ITEM 1 Next Steps**

Have students review the diagram of a simple wave in their notebooks and then revise their answers as needed.

*Focus on Disciplinary Core Ideas*
*Focus on Crosscutting Concepts*

### Item 2

This item provides evidence that students know that all waves have a repeating pattern and transfer energy.

| Code | If the student . . . |
|---|---|
| 3 | writes that all waves have a back-and-forth pattern of motion (or repeating pattern) and transfer energy; may include extraneous information like wavelength. |
| 2 | writes that all waves have a back-and-forth pattern of motion or that they transfer energy, but not both. |
| 1 | writes any other answer. |
| 0 | makes no attempt. |

**ITEM 2 Next Steps**

Have students consider their notes from the spring wave model and discuss this item in small groups. Students then reflect and revise their answers as needed.

*Focus on Disciplinary Core Ideas*
*Focus on Crosscutting Concepts*

### Item 3

This item provides evidence that students can identify the media through which waves travel (systems and system models).

| Code | If the student . . . |
|---|---|
| 2 | lists media from top to bottom: metal coil, water, air. |
| 1 | writes any other answer. |
| 0 | makes no attempt. |

**ITEM 3 Next Steps**

Use the group consensus/whiteboard strategy to help students reflect on their answers to this item. See the Next-Step Strategies section in this chapter.

*Focus on Science and Engineering Practices*
*Focus on Disciplinary Core Ideas*
*Focus on Crosscutting Concepts*

### Item 4

This item provides evidence that students can calculate the speed of a wave by knowing its frequency and wavelength (systems and system models).

| Code | If the student . . . |
|---|---|
| 3 | solves the equation; includes units. |
| 2 | solves the equation; makes error with units. |
| 1 | writes anything else. |
| 0 | makes no attempt. |

**ITEM 4 Next Steps**

Have students refer to their answers from notebook sheet 2, *Transverse Waves*. Have groups discuss any discrepancies, then revise their answers as needed.

# SAMPLE ASSESSMENT ITEMS

ANSWERS

## INVESTIGATIONS 1–2 I-CHECK
WAVES

5. A student taps a drum and you hear the noise.
   a. Describe how a sound wave is made when the student taps the drum.
   The drum vibrates and pushes air particles. The particles are pushed away in a repeating pattern, creating a compression wave.
   b. Describe how the sound wave travels from the drum to your ear.
   The wave travels by pushing air particles into a smaller area (compression) each time the drum is tapped. The compressed air travels to your ear.
   c. The student increases the amplitude of the drum noise. Which of the following is true? *(Mark all that apply.)*
   - X The sound wave will transfer more energy.
   - X The sound will be louder.
   - ___ The frequency will increase.
   - ___ The pitch will increase.
   - ___ The wavelength will increase.

6. A city wants to build a new sports arena. What are some possible constraints that a building engineer will need to consider?
   Possible constraints include money/budget, time, climate/weather, size of audience, needs of sports, and geography/location.



Waves Course
Investigations 1–2 I-Check
Page 2 of 4

### NOTE
Look for these resources in the Assessment section in *Teacher Resources* on FOSSweb.
- Assessment chapter
- Assessment masters
- Coding guides
- Assessment charts

*Focus on Science and Engineering Practices*
*Focus on Disciplinary Core Ideas*
*Focus on Crosscutting Concepts*

### Item 5a

This item provides evidence that students can explain how a sound wave is created when a drum is tapped (systems and system models; cause and effect).

| Code | If the student . . . |
|---|---|
| 3 | explains that vibrations from the drum push air particles, or create a compression wave in the air. |
| 2 | mentions vibrations or that something happens to the air; does not mention the compression wave. |
| 1 | writes any other answer. |
| 0 | makes no attempt. |

### Item 5b

This item provides evidence that students can explain how a sound wave travels from its source to a listener's ear (systems and system models; cause and effect).

| Code | If the student . . . |
|---|---|
| 3 | explains that a sound wave travels through the medium (air); describes how it compresses (or pushes) air as it travels. |
| 2 | explains that the wave travels through the medium (air), or mentions that the wave compresses air. |
| 1 | writes any other answer. |
| 0 | makes no attempt. |

### Item 5c

This item provides evidence that students understand that increasing the amplitude causes a sound wave to transfer more energy and become louder (effect).

| Code | If the student . . . |
|---|---|
| 3 | marks only the first two statements. |
| 2 | marks the first two statements and incorrectly marks one other statement. |
| 1 | marks any other way. |
| 0 | makes no attempt. |

*Focus on Science and Engineering Practices*
*Focus on Disciplinary Core Ideas*

### Item 6

This item provides evidence that students can describe possible constraints an engineer might need to consider when designing a project.

| Code | If the student . . . |
|---|---|
| 3 | describes at least two possible constraints. |
| 2 | describes one constraint. |
| 1 | writes anything else. |
| 0 | makes no attempt. |

### ITEM 5a Next Steps
Have students review "Sound Waves" in *FOSS Science Resources*. Discuss the item in small groups after reviewing the reading, and have students revise their answers as needed.

### ITEM 5b Next Steps
Have students review the diagrams in "Sound Waves" in *FOSS Science Resources*. You can also project teacher master G, *Sound Waves*, for reference. Students review the information, reflect, and revise their answers as needed.

### ITEM 5c Next Steps
Have students check their science notebooks for information to confirm or refute their answers to this item. If that information is not there, take this opportunity to discuss with students what kinds of information are important to record.

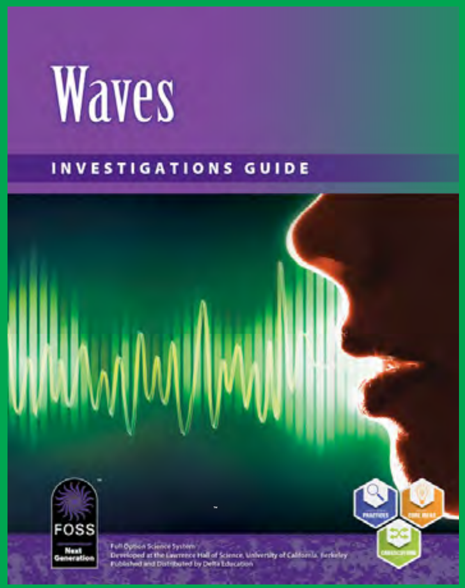
### ITEM 6 Next Steps
Have students review "Acoustic Engineering" in *FOSS Science Resources*. You can also project teacher master H, *Engineering Criteria and Constraints*, for reference. Students review the information, reflect, and revise their answers as needed.

# FOSS Includes:

## Investigations Guide

The Investigations Guide is a spiral-bound guide containing everything you need to teach the module. FOSS active investigation lesson plans include:

- Three-dimensional learning objectives
- Relevant and local phenomena storylines with driving questions
- Sense-making discussions
- Embedded assessment and "What to Look For" guidance
- Vocabulary reviews
- English language support strategies
- ELA strategies and connections




## Science Resources Student Book

The *FOSS Science Resources* student book contains readings developed to reinforce, extend, or apply core ideas covered during FOSS active investigations. Readings give students opportunities to:

- Use text to obtain, evaluate, and communicate information
- Use evidence to support their ideas during sense-making discussions and focus question responses
- Integrate information from multiple sources
- Interpret graphs, diagrams, and photographs to build understanding

Available in print and as an interactive eBook in English and Spanish.


▶ **Images on this page include actual components, resources and/or materials provided in FOSS kits.**

## Equipment Kit

FOSS provides the equipment needed for all the investigations, including metric measuring tools. Our high-quality, classroomtested materials are long-lasting and packaged by investigation to facilitate preparation and clean up. There is enough permanent equipment in each kit for 32 students. Consumable materials are supplied for three uses. Convenient grade-level and refill kits are available.


## Technology

Online resources include duplication masters, eInvestigations Guide, teaching slides, streaming videos, virtual investigations, and tutorials, as well as a library of teacher resources, including access and equity, three-dimensional teaching and learning, and environmental literacy.

SCAN HERE FOR A TOUR OF FOSSWEB!

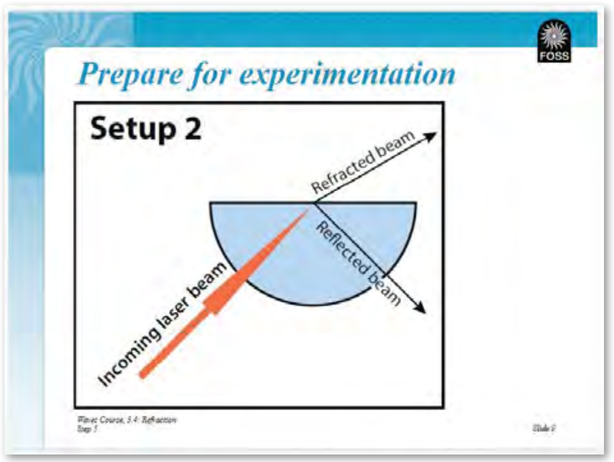
# FOSSweb on ThinkLink

FOSSweb digital resources are delivered on School Specialty's curriculum platform called ThinkLink.

- Supports single sign-on and class management with Google classroom and learning management systems.
- Provides access to both teacher and student digital resources, including duplication masters, teaching slides, FOSSmap online assessment, streaming videos, and online activities.

## Teaching Slides

Downloadable and editable slides from FOSSweb can be used to facilitate each part of each investigation. Teaching slides are available as Google slides in English and Spanish.

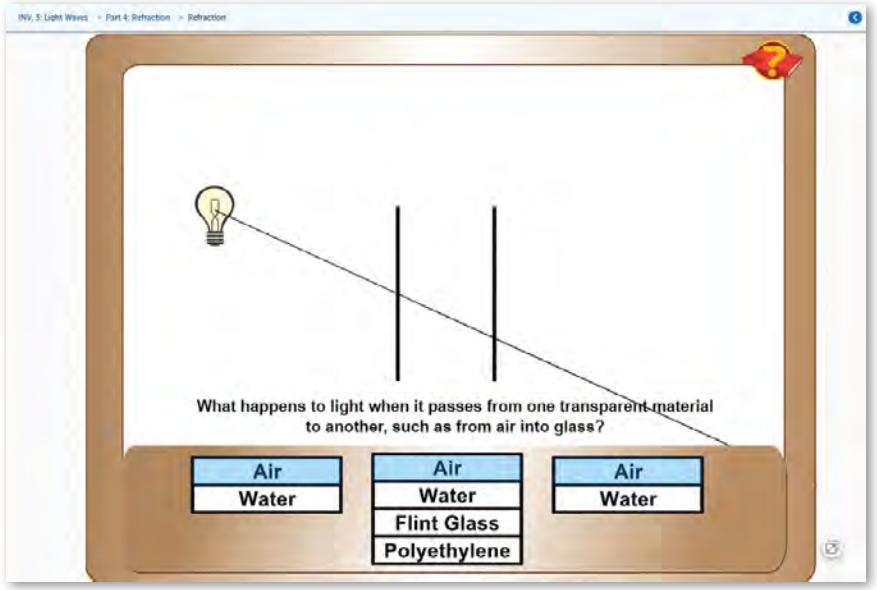



## Streaming Videos

Engaging content videos in English and Spanish were developed to specifically support FOSS investigations.


## Online Activities

Engaging simulations developed to address core ideas in FOSS, and interactive virtual investigations and tutorials offer additional content support for students.




## Interactive eBooks

Keep your students engaged while teaching literacy skills with interactive *FOSS Science Resources* eBooks. The eBooks include integrated audio with text syncing and links to online activities and videos that bring the photos to life.

# Join the Next Generation.

*Recommended 6-8 Scope and Sequence*

## FOSS® Middle School Scope & Sequence

<table>
<tr><th>Grade</th><th colspan="5">Integrated Middle Grades</th><th>STEM Enrichment</th></tr>
<tr><td>8</td><td>Heredity & Adaptation*<br>ES, LS</td><td>Electromagnetic Force*<br>PS, ES, E</td><td>Gravity & Kinetic Energy*<br>PS, E</td><td>Waves*<br>PS, E</td><td>Planetary Science<br>PS, ES</td><td rowspan="3">Variables & Design†<br>Grades 5-8<br>E</td></tr>
<tr><td>7</td><td colspan="2">Chemical Interactions<br>PS, ES, E</td><td colspan="2">Earth History<br>PS, ES, LS</td><td>Populations and Ecosystems<br>ES, LS, E</td></tr>
<tr><td>6</td><td colspan="2">Weather and Water<br>PS, ES, E</td><td colspan="2">Diversity of Life<br>LS</td><td>Human Systems Interactions*<br>LS</td></tr>
</table>

PS: Physical Science content, ES: Earth Science content, LS: Life Science content, E: Engineering content *Half-length courses
†STEM Enrichment courses and modules can supplement the FOSS core curriculum or be purchased separately for STEM electives or extracurricular activities.

## Learn more.

Find your local FOSS/Delta Education representative at **FOSSNextGeneration.com/Sales**

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