PhD SCIENCE®
TEKS EDITION

Level 4 Energy

Teacher Edition

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Level 4 Energy

Contents

Module Overview

ESSENTIAL QUESTION

How do windmills change wind to light?

Introduction

> *All the life of the universe may be regarded as manifestations of energy masquerading in various forms, and all the changes in the universe as energy running about from one of these forms to the other, but always without altering the total amount.*
>
> —Sir James Jeans, 1929 (1945, 104)

The module begins and ends with students observing the anchor phenomenon—windmills that harness the wind to generate electricity. Throughout the module, students explore the Essential Question, **How do windmills change wind to light?**, and apply key conceptual understandings to build and refine an anchor model to explain the anchor phenomenon. At the end of the module, students use their knowledge of energy classification, transfer, and transformation to explain the windmill phenomenon and apply these concepts in new contexts during an engineering challenge and the End-of-Module Assessment. Through these experiences, students begin to develop the enduring understanding that energy cannot be created or destroyed, but it can be transferred and transformed to be more useful.

Lessons 1 through 5 address the Concept 1 Focus Question: **What is energy?** Students begin to grasp that energy is why things happen in the world around them. They observe different phenomena that indicate energy is present and classify those energy phenomena in categories. Lessons 1 through 3 introduce the anchor phenomenon through paintings and photographs of windmills as well as through hands-on activities in which students build physical windmill models.

Students are also introduced to William Kamkwamba, a real student from Malawi and the subject of *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010), who built a windmill to generate electricity for his family. In doing so, he helped address famine in his community. Reflecting on William's story, students organize their questions on a driving question board and draw a class consensus model of a windmill. Students will revisit the driving question board and an anchor model throughout the module to build a coherent understanding of energy. Engaging in these practices from the very first lesson allows students to take an active role in the educational process and gives teachers insight into students' background knowledge and current understanding of energy. In Lessons 4 and 5, students observe energy through a series of hands-on Energy Stations. Students classify the energy phenomena that indicate the presence of energy in categories such as sound, light, heat, electricity, and the motion of objects.

Lessons 6 through 9 address the Concept 2 Focus Question: **How does energy transfer from place to place?** Students develop the understanding that energy can transfer (or move) from one object to another through collisions. In Lessons 6 and 7, students plan and conduct investigations to study the relationship between energy and speed. They observe that the amount of energy transferred to an object affects its speed—transferring more energy to an object causes it to move faster. Lessons 8 and 9 focus on collisions. Students conduct an investigation and develop a model to explain how energy can be transferred by moving objects. In observing a moving object colliding with a stationary object, they note that an object traveling at greater speed transfers more energy to the stationary object and pushes it farther than the same object traveling at a slower speed. They apply their understanding of energy transfer to the anchor phenomenon, updating the anchor model to show that energy is transferred from the windmill's blades to its wires and then to the light bulb. Students also notice that collisions typically produce sound and heat, which raises questions about the next concept—energy transformation.

Lessons 10 through 16 address the Concept 3 Focus Question: **How does energy transform?** Students learn that energy transforms when one energy phenomenon changes into any other energy phenomenon. In Lessons 10 and 11, students identify patterns of energy transformation at Energy Transformation Stations. By building a simple generator in Lessons 12 through 14, students observe how a windmill generates electricity by transforming mechanical energy. In Lesson 15, students apply their knowledge of energy transformation to the anchor phenomenon for a final revision of the anchor model. In Lesson 16, students revisit *The Boy Who Harnessed the Wind*. This real-world story leads to the next lessons, in which students harness energy to solve a problem in an engineering challenge.

Lessons 17 through 26 allow students to apply their knowledge of energy classification, transfer, and transformation in an engineering challenge and End-of-Module Assessment, further building on their understanding of the Essential Question: **How do windmills change wind to light?** The story of William Kamkwamba shows students that anyone can be an engineer and solve problems in their own community. In Lessons 17 through 22, students participate in an engineering challenge. Students imagine that they are without power after a devastating flood in their town. They build a device to harness energy by using materials from the classroom and home. In Lesson 23, student groups present their devices to the class and summarize their design processes, including their struggles and successes. Students then participate in a Socratic seminar on energy in Lesson 24, revisiting the module questions and synthesizing their understanding. In Lesson 25, students reflect on their study of energy and apply their conceptual understandings in an End-of-Module Assessment. Finally, the class debriefs the End-of-Module Assessment in Lesson 26, giving the teacher and students an opportunity to revisit concepts that need further explanation and clarify misconceptions.

Module Map

Anchor Phenomenon: Windmills at Work

Essential Question: How do windmills change wind to light?

Energy can be neither created nor destroyed, but it can be transferred and transformed to be more useful.

Concept 1: Energy and Its Classifications

Focus Question: What is energy?

Energy is why things happen. People can observe phenomena that indicate the presence of energy. It can be useful to classify those indicators into categories such as sound, light, heat, electricity, and the motion of objects.

Phenomenon	Phenomenon Question and Objectives	Texas Essential Knowledge and Skills for Science	English Language Proficiency Standards
Windmills at Work *Phenomenon Question: How do windmills harness the wind?*	Everything that happens in a system is caused by energy. ▪ Lesson 1: Make observations to generate questions about how windmills harness the wind. ▪ Lesson 2: Create a model windmill that generates electricity. ▪ Lesson 3: Ask questions about energy.	4.2A 4.2D 4.2F 4.3B 4.3C 4.6A 4.6C	3C 3E 4C
Energy Indicators *Phenomenon Question: How do we know energy is present?*	Light, sound, temperature change, and motion indicate the presence of energy in a system. ▪ Lesson 4: Observe indicators of the presence of energy. ▪ Lesson 5: Classify indicators of the presence of energy.	4.2D 4.2F 4.3B 4.6A	1E 4C 5G

Concept 2: Energy Transfer

Focus Question: How does energy transfer from place to place?

Energy can transfer between objects through collisions and from place to place through electric currents, sound, heat, and light.

Phenomenon	Phenomenon Question and Objectives	Texas Essential Knowledge and Skills for Science	English Language Proficiency Standards
Effect of Energy on Speed *Phenomenon Question: What is the relationship between energy and speed?*	The speed of an object is related to the energy of the object. ▪ Lesson 6: Describe the relationship between energy and speed. ▪ Lesson 7: Interpret data showing that greater energy input enables greater speed.	4.2A 4.2B 4.2C 4.2D 4.2F 4.3A 4.3B 4.4 4.6A	3B 5F
Energy Changes during a Collision *Phenomenon Question: What happens to energy when objects collide?*	Energy in a system can transfer between objects through collisions, causing changes in their motion. ▪ Lesson 8: Predict the transfer of energy of motion between objects during a collision. ▪ Lesson 9: Explain the transfer of energy of motion between objects through forces in a collision.	4.2A 4.2C 4.2D 4.2F 4.3A 4.3B 4.4 4.6D	2C 4A 5G

Concept 3: Energy Transformation

Focus Question: How does energy transform?

Energy transformation occurs when one phenomenon indicating the presence of energy changes into any other energy phenomenon.

Phenomenon	Phenomenon Question and Objectives	Texas Essential Knowledge and Skills for Science	English Language Proficiency Standards
Changes in Energy Indicators *Phenomenon Question: What do we observe when energy transforms?*	Energy transforms by changing from one form to another. ▪ Lesson 10: Observe transformation of energy to produce motion, light, sound, and temperature change. ▪ Lesson 11: Explain that energy may transform to produce new phenomena, such as motion, light, sound, and temperature change.	4.2B 4.2D 4.2F 4.4 4.6A	3F 4D
Generating Electricity *Phenomenon Question: How do windmills generate electricity?*	A generator can be used to transform mechanical energy into electrical energy. ▪ Lesson 12: Plan to build generators to transform mechanical energy into electrical energy. ▪ Lessons 13–14: Build generators to transform mechanical energy into electrical energy.	4.2F 4.3B 4.3C 4.6A 4.6B 4.6C	3D 5F
Windmills at Work *Essential Question: How do windmills change wind to light?*	Everything that happens can be explained by the transfer and transformation of energy. ▪ Lesson 15: Model how windmills transfer and transform energy. ▪ Lesson 16: Explain that energy makes things happen when it is transferred and transformed.	4.2A 4.2F 4.3B 4.3C 4.6A	2E 2F

Application of Concepts

Task	Phenomenon Question and Objectives	Texas Essential Knowledge and Skills for Science	English Language Proficiency Standards
Engineering Challenge *Phenomenon Question: How can we apply our knowledge of energy to solve a problem?*	The engineering design process can be used to create a device to transfer energy and transform it from an available form into the desired form. ▪ Lessons 17–23: Apply the engineering design process to construct and refine a device that transforms energy.	4.2A 4.2E 4.2F 4.3B 4.3C 4.6A 4.6C	3E 3F
End-of-Module Socratic Seminar, Assessment, and Debrief *Essential Question: How do windmills change wind to light?*	In a system, specific indicators of energy can be generated through energy transfers and transformations. ▪ Lesson 24: Explain changes in a system as the transfer and transformation of energy. (Socratic Seminar) ▪ Lesson 25: Explain changes in a system as the transfer and transformation of energy. (End-of-Module Assessment) ▪ Lesson 26: Explain changes in a system as the transfer and transformation of energy. (End-of-Module Assessment Debrief)	4.2C 4.2D 4.2F 4.3B 4.6A 4.6C	2F 3G

Focus Standards*

Texas Essential Knowledge and Skills for Science

4.1 Scientific investigation and reasoning. The student conducts classroom and outdoor investigations following home and school safety procedures and environmentally appropriate practices. The student is expected to

- 4.1A *demonstrate safe practices and the use of safety equipment as described in Texas Education Agency–approved safety standards during classroom and outdoor investigations using safety equipment, including safety goggles or chemical splash goggles, as appropriate, and gloves, as appropriate; and*
- 4.1B *make informed choices in the use and conservation of natural resources and reusing and recycling of materials such as paper, aluminum, glass, cans, and plastic.*

4.2 Scientific investigation and reasoning. The student uses scientific practices during laboratory and outdoor investigations. The student is expected to

- 4.2A *plan and implement descriptive investigations, including asking well defined questions, making inferences, and selecting and using appropriate equipment or technology to answer his/her questions;*
- 4.2B *collect and record data by observing and measuring, using the metric system, and using descriptive words and numerals such as labeled drawings, writing, and concept maps;*
- 4.2C *construct simple tables, charts, bar graphs, and maps using tools and current technology to organize, examine, and evaluate data;*
- 4.2D *analyze data and interpret patterns to construct reasonable explanations from data that can be observed and measured;*
- 4.2E *perform repeated investigations to increase the reliability of results; and*
- 4.2F *communicate valid oral and written results supported by data.*

4.3 Scientific investigation and reasoning. The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to

- 4.3A *analyze, evaluate, and critique scientific explanations by using evidence, logical reasoning, and experimental and observational testing;*
- 4.3B *represent the natural world using models such as the water cycle and stream tables and identify their limitations, including accuracy and size; and*
- 4.3C *connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.*

4.4 Scientific investigation and reasoning. The student knows how to use a variety of tools and methods to conduct science inquiry. The student is expected to

- 4.4 *collect, record, and analyze information using tools, including calculators, microscopes, cameras, computers, hand lenses, metric rulers, Celsius thermometers, mirrors, spring scales, balances, graduated cylinders, beakers, hot plates, meter sticks, magnets, collecting nets, and notebooks; timing*

*The bold text identifies standards that students should master in this module. The italicized text identifies standards that students will develop knowledge of in this module and should master in later modules. Some italicized standards are part of the assessments in this module, but they will be assessed throughout the year.

devices; and materials to support observation of habitats of organisms such as terrariums and aquariums.

4.6 Force, motion, and energy. The student knows that energy exists in many forms and can be observed in cycles, patterns, and systems. The student is expected to

4.6A **differentiate among forms of energy, including mechanical, sound, electrical, light, and thermal;**

4.6B **differentiate between** conductors and **insulators of** *thermal* **and electrical energy**;

4.6C **demonstrate that electricity travels** in a closed path, **creating an electrical circuit**; and

4.6D **design a descriptive investigation to explore the effect of force on an object** such as a push or pull, gravity, friction, or magnetism.

Building Content Knowledge

Kindergarten through Level 2 lay the foundation for understanding force, motion, and energy as students observe and record ways that objects can move and then compare patterns of movement. In Level 3, students demonstrate and observe how pushing and pulling on objects can change their position and motion, and students observe forces acting on objects.

In Level 4, students build on their knowledge of force, motion, and energy as they investigate energy indicators and transformation and determine the relationship between speed and energy. Students begin the Energy Module by making observations to generate questions about how windmills harness the wind. Students are introduced to the book *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010), and they create a model windmill. Students use the model windmill to create an anchor model that is used throughout the module to apply their learning of energy and electricity (4.3B). Students ask questions about the windmill phenomenon and the concept of energy that drive their learning throughout the module.

Throughout Concept 1, students explore the Concept 1 Focus Question: **What is Energy?** They first observe indicators of the presence of different forms of energy, and then they use their observations to classify indicators of energy into categories, such as sound, light, temperature change, and motion (4.6A).

In Concept 2, students design an investigation to describe the relationship between energy and speed (4.2A). Through analysis of their data and interpretation of patterns (4.2D), students find that transferring more energy to an object allows it to move with more speed. Students then build on their understanding by investigating how energy can transfer between objects through collisions, causing changes in the objects' motion (4.6D).

In Concept 3, students develop a model to show how energy transforms (4.3B). They identify patterns and relationships in their observations to understand that energy that is transferred by light, sound, and heat may transform to produce new energy phenomena, such as motion, light, sound, and temperature change. Students then plan and build generators to transform mechanical energy into electrical energy (4.6A, 4.6B, 4.6C). Students revise the class anchor model (4.3B) to show how windmills transfer and transform energy and explain that energy makes things happen when it is transferred and transformed (4.6A). Students revisit the story of William Kamkwamba in preparation for the engineering challenge, during which they design a device that transforms energy from an available form into the desired form (4.2A, 4.6A, 4.6C). Students then reflect on their learning about energy and apply their understanding of energy to a new context in the End-of-Module Assessment.

Key Terms

In this module, students learn the following terms through investigations, models, explanations, class discussions, and other experiences.

- Collision
- Energy
- Energy transfer
- Energy transformation
- Generator
- Indicators of energy
- Speed
- System

Safety Considerations

The safety and well-being of students are of utmost importance in all classrooms, and educators must act responsibly and prudently to safeguard students. Science investigations frequently include activities, demonstrations, and experiments that require extra attention regarding safety measures. Educators must do their best to ensure a safe classroom environment.

The hands-on, minds-on activities of this module focus on energy. Students use various materials to investigate aspects of energy when visiting energy stations, build a windmill model by using Snap Circuits® by Elenco®, conduct experiments, construct a generator, and design and build their own device. Some of the more important safety aspects to implement in this module follow:

1. **Teachers must explain and review safety expectations to students before each activity.**
2. **Students must listen carefully to and follow all teacher instructions.** Instructions may be verbal, on classroom postings, or written in the Science Logbook or other handouts.
3. **Students must demonstrate appropriate classroom behavior (e.g., no running, jumping, pushing) during science investigations.** Students must handle all supplies and equipment carefully and respectfully.
4. **Students and adults must wear personal protective equipment (e.g., safety goggles) during investigations that require the use of such equipment.** In this module, anyone working with wires, ball bearings, and spinning fan or windmill blades must wear goggles.
5. **Debris must be cleaned up immediately.** During investigations, items can fall to the floor even when everyone is careful. Immediate removal of debris from the floor is essential to help prevent slips and falls.

6. **Students must never place any materials in their mouth during a science investigation.**
7. **Put away all food and drinks during science investigations.** Food and drinks can be easily contaminated by investigation materials. Additionally, spilled food or drinks can disrupt investigations.
8. **Monitor student activity on the internet.** If students are permitted access to the internet for science research purposes, their activity must be monitored to ensure that it conforms with school and district policies.

More information on safety in the elementary science classroom appears in the Implementation Guide. Teachers should always follow their school's or district's health and safety guidelines. For additional information on safety in the science classroom, consult the Texas Education Agency–approved safety standards (4.1A).

Additional Reading for Teachers

Energy: Stop Faking It! Finally Understanding Science So You Can Teach It by William C. Robertson and Brian Diskin (2002)

Teaching Energy across the Sciences, K–12 by Jeffrey Nordine (2016)

Additional Reading for Students

Energy Island: How One Community Harnessed the Wind and Changed Their World by Allan Drummond (2015)

Lessons 1–3
Windmills at Work

Prepare

Lesson 1 begins with a discussion of students' experiences with wind. Students look at paintings and photographs of windmills and share their observations of how windmills might work. In Lesson 2, students are introduced to the story of William Kamkwamba, a boy who built a windmill to harness the wind and help provide his community with electricity and water. To see the power of wind for themselves, students build their own windmills and observe the transfer of energy. In Lesson 3, students create an anchor model to record their initial understanding of how windmills work. They then develop a driving question board that will guide student learning throughout the module.

Concept 1: Energy and Its Classifications

Focus Question

What is energy?

Phenomenon Question

How do windmills harness the wind?

Student Learning

Knowledge Statement

Everything that happens in a system is caused by energy.

Objectives

- Lesson 1: Make observations to generate questions about how windmills harness the wind.
- Lesson 2: Create a model windmill that generates electricity.
- Lesson 3: Ask questions about energy.

Texas Essential Knowledge and Skills Addressed

- 4.2A Plan and implement descriptive investigations, including **asking well defined questions, making inferences,** and selecting and using appropriate equipment or technology to answer his/her questions. (Addressed)
- 4.2D **Analyze data and interpret patterns to construct reasonable explanations from data that can be observed** and measured. (Addressed)
- 4.2F **Communicate** valid oral and written **results** supported by data. (Addressed)
- 4.3B **Represent the natural world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)
- 4.3C **Connect grade-level appropriate science concepts with** the history of science, science careers, and **contributions of scientists**. (Addressed)
- 4.6A **Differentiate among forms of energy, including** mechanical, sound, **electrical, light,** and thermal. (Introduced)
- 4.6C **Demonstrate that electricity travels** in a closed path, **creating an electrical circuit.** (Introduced)

English Language Proficiency Standards Addressed

- 3C Speak using a variety of grammatical structures, sentence lengths, sentence types, and connecting words with increasing accuracy and ease as more English is acquired.
- 3E Share information in cooperative learning interactions.
- 4C Develop basic sight vocabulary, derive meaning of environmental print, and comprehend English vocabulary and language structures used routinely in written classroom materials.

Materials

		Lesson 1	Lesson 2	Lesson 3
Student	Science Logbook (Lesson 1 Activity Guide)	●		
	Pinwheel Investigation (per student): pencil, paper plate, pushpin, scissors	●		
	Science Logbook (Lesson 2 Activity Guide)		●	
	Materials from Snap Circuits® Green kit by Elenco® (per group): base grid, fan, motor, pivot stand base, pivot post, pivot top, black jumper wire, red jumper wire, red LED		●	
	Science Logbook (Module Question Log, Lesson 3 Activity Guide)			●
	Windmill model drawn in Lesson 2			●
Teacher	Windmill Gears Photograph (Lesson 1 Resource A)	●		
	Windmill Grinding Photograph (Lesson 1 Resource B)	●		
	The Boy Who Harnessed the Wind by William Kamkwamba and Bryan Mealer (2010)		●	
	Windmill Model Setup Instructions (Lesson 2 Resource)		●	
	Modern Wind Turbine Photograph (Lesson 3 Resource A)			●
	Wind Farm Photograph (Lesson 3 Resource B)			●
	Wind Farm Diagram (Lesson 3 Resource C)			●
Preparation	Open *Windmill, 1917* by Piet Mondrian: http://phdsci.link/1017.	●		
	Open *Oostzijde Mill with Extended Blue, Yellow, and Purple Sky, 1907–08* by Piet Mondrian: http://phdsci.link/1018.	●		
	Cue “Windmill Gears” video (andy b 2008): http://phdsci.link/1019.	●		
	Open maps of Africa and Malawi: http://phdsci.link/1158.		●	

Lesson 1

Objective: Make observations to generate questions about how windmills harness the wind.

Launch 5 minutes

▶ Why do people care about the wind?

- *It can knock you down. It made a tree fall on the power lines near my house.*
- *Wind helps you feel cooler on a hot day.*
- *We learned last year that the wind can do a lot of damage.*

▶ What was the most powerful wind you have ever experienced?

- *I saw a tornado. It had strong winds that swirled.*
- *I was in a hurricane and the wind was knocking over trees.*
- *The wind knocked my trash can over once and made stuff fly all over the place.*

▶ What was the weakest wind you have ever experienced?

- *Some days it feels like there is no wind at all.*
- *A ceiling fan set on the lowest power blows just a little wind.*

Agenda

Launch (5 minutes)

Learn (35 minutes)

- Notice and Wonder about Windmills (15 minutes)
- Construct Miniature Windmills (20 minutes)

Land (5 minutes)

English Language Development

Understanding the term *wind* is essential to this module. English learners may benefit from seeing photographs or videos that show the effects of wind.

Draw attention to student responses about wind moving objects. Then, display the two Piet Mondrian paintings—*Windmill, 1917* (left) (http://phdsci.link/1017) and *Oostzijde Mill with Extended Blue, Yellow, and Purple Sky, 1907–08* (right) (http://phdsci.link/1018)—and ask students what type of structure is being depicted in these paintings.

Inform students that, in this lesson, they will explore the Phenomenon Question **How do windmills harness the wind?**

English Language Development

Harness is a verb that is used repeatedly in this module. Take this opportunity to introduce the term explicitly, using a process such as this:

- Pronounce *harness* and have students repeat. Say *har*-ness in syllables, and then repeat the full word.
- Share a student-friendly explanation. For example, "If you harness something, you bring it under your control and use it."
- Discuss examples using *harness* in different contexts. For example, "The farmer harnessed her horse to a cart," or, "People built a dam to harness the power of the Colorado River."

Note that *harness* does not have word parts or Spanish cognates that will help students understand its meaning. In Spanish, the verb *aprovechar* is used when speaking of using sources of natural energy.

English learners may benefit from explicit introduction of other words, such as *windmill*, in this lesson set. After introducing these and other important words, provide scaffolds for English learners as they use the words in speaking, writing, and investigating. For more information on language scaffolds, see the English Language Development section of the Implementation Guide.

Content Area Connection: English

Introduce the phenomenon of wind with a poem such as "Who Has Seen the Wind" by Christina Rossetti or "The Wind" by James Reeves. Present the poem as a riddle, replacing the word *wind* with a blank space. Read and discuss the poem. Ask students to infer the poem's topic and explain their reasoning with evidence from the text.

Learn 35 minutes

Notice and Wonder about Windmills 15 minutes

Continue to display the two Piet Mondrian paintings. Tell students to use the notice and wonder chart in their Science Logbooks (Lesson 1 Activity Guide) to record what they notice and wonder as they look at the windmills.

Invite students to share their observations and questions. While students listen to their peers, they can use nonverbal signals to indicate whether they recorded a similar thought. Write students' observations and questions on a class notice and wonder chart as they share.

Sample student responses:

I Notice	I Wonder
▪ *Windmills are really big. That one is taller than the trees.* ▪ *They look like a house with a fan on top.* ▪ *The windmill fans have holes in them. They also have some kind of stick that connects to the house.* ▪ *The windmills in the paintings look very similar.* ▪ *Both windmills look like they are near water.*	▪ *What's inside the house part of the windmill?* ▪ *What do people use windmills for? How do they work?* ▪ *How does the windmill spin if the fans have holes in them?* ▪ *Are these paintings of the same windmill? Do all windmills look like this?* ▪ *Why don't these windmills look like the tall, skinny ones that I have seen before?*

Spotlight on Knowledge and Skills

By sharing their initial thoughts and questions, students improve their abilities to observe evidence, ask questions, and notice patterns about windmills, such as cause-and-effect relationships. These abilities lay the foundation for developing the windmill anchor model in Lesson 3.

Content Area Connection: English

During science discussions, remind students of classroom expectations for speaking and listening. For example, remind students to ask each other to clarify questions and link their ideas to others' remarks (3C). See Speaking and Listening Supports in the Implementation Guide for resources to promote respectful, productive discourse.

Teacher Note

These activities are designed to elicit students' prior understanding. Rather than correct students, listen to how they respond and make sense of what they see and hear.

Refer to students' questions about how windmills work. Tell students they will view photographs and a video from inside the body of a real windmill.

Display the photographs shown below (Lesson 1 Resources A and B).

▶ How do you think these windmills work?

- *I think the wooden wheel turns.*
- *The different pieces might make each other spin, like gears.*
- *It looks like the white wheel rolls over the dust. I wonder why?*

Play "*Windmill Gears*" (andy b 2008), a video of a windmill's millstones grinding (http://phdsci.link/1019). Ask students to share new ideas about how the windmill might work.

If students do not infer that the wind causes the mill's internal movements, ask them to think about what the video shows.

▶ What causes the wheel inside to move?

- *I think the wind spins the fan, and the fan turns the wheel.*
- *The fan must connect to the wheels. Maybe that's what the sticks in the paintings do.*
- *When the windmill blades spin, the stone wheel rolls and crushes the powder.*

Teacher Note

Student responses during the notice and wonder activity will vary significantly across classrooms. The primary responses to look for in the wonder column are those that relate to how windmills work and what they do. These questions lead into the activities that follow. If students do not ask these questions, show one of the paintings again and ask questions to draw students' attention to the body beneath the windmill blades.

Additionally, students who are familiar with windmills that generate electricity may mention them here. If so, these ideas may be leveraged in the Lesson 2 Launch to motivate the investigation of modern windmills.

English Language Development

The following line of questioning involves using vocabulary such as *windmills*. English learners may benefit from additional scaffolding in the form of sentence frames. Consider using sentence frames like the ones below to scaffold this conversation.

- Windmills might work by _______.
- I think windmills work with _______.
- In the windmill picture, I see _______. That makes me think _______.

For more information about how to construct sentence frames, refer to the English Language Development section of the Implementation Guide (3C).

Explain that wind pushes the blades of the windmill, causing the blades to spin. The spinning blades turn the gears, causing the millstones to roll. The millstones grind coarse substances (e.g., wheat grain) into powder (e.g., flour).

▶ How would a strong wind affect the windmill?

- *The blades would spin really fast and the mill would grind faster.*
- *You could make a lot of flour when the mill grinds faster.*

▶ How would a weak wind affect the windmill?

- *It might not spin at all, so the mill would not grind.*
- *It would spin really slowly, and the mill would grind slowly.*

Check for Understanding

As students respond, listen for them to make a connection between the strength of the wind and the activity of the windmill.

Evidence

Look for evidence that all students connect

- more wind with faster movement of the windmill blades and the millstones, and
- less wind with slower movement of the windmill blades and the millstones.

Next Steps

In the next activity, students construct a miniature windmill. Use the windmill to show students who had difficulty making the above connection how wind strength affects the movement of the windmill blades.

It is fine if students mention energy in their answers or discussions, but it may help to avoid discussion of the concept of energy until it is formally introduced. Later in the module, students study the relationship between speed and energy through an investigation. Energy is not specifically discussed until Lesson 3.

Construct Miniature Windmills 20 minutes

Explain that people have used windmills throughout history to harness the wind to do work, such as grinding wheat into flour for bread. Tell students they will construct their own miniature windmill to explore the power of wind. To begin, students design small windmills out of paper plates.

Teacher Note

Many students will only know of flour as something that is bought at a store. Explain the harvesting of wheat or grains in the field and the subsequent grinding for use as needed.

Differentiation

During this discussion, post a picture of a windmill and label the parts that students mention, such as the fan, blades, gears, and millstone. Students may benefit from repeating each new term aloud after it is introduced and labeled.

Spotlight on Knowledge and Skills

Science impacts people's lives in many ways each day. Throughout this module, students learn that energy is needed to make everything happen and that people can develop tools, such as windmills, to harness energy and transform it into a desired form to do work.

Split the class into small groups and distribute the pinwheel investigation materials to each student. Instruct students to use the materials however they wish to construct a working miniature windmill. Ask students to work independently on their windmills but share ideas with their groups as they work. Allow time for productive struggle, and encourage students to share designs that work and designs that do not. Continue to circulate to support students and refer to the windmill images as needed.

Call the class together and debrief as a group.

▸ What happens when you blow on your windmill?

- *When I blow hard, the windmill spins fast.*
- *When I walk around holding my windmill, it spins a little.*
- *If I only blow a little, sometimes it does not move at all.*

▸ What did you notice helped the windmill work better?

- *The blades need to be curved to spin.*
- *At first the pushpin hole is tight, but as I spin the windmill, it gets looser and my windmill spins better.*

Teacher Note

Save students' pinwheels for use in the engineering challenge in Lessons 17–23.

Land 5 minutes

After students finish discussing their designs, ask them to think again about the windmills in the paintings.

▸ How does your windmill compare to the windmills in the paintings?

- *Our windmills spin just like the ones in the pictures.*
- *Our windmills are much smaller and simpler.*
- *Our windmills don't have a house attached.*
- *The other windmills can grind wheat. Ours just spin.*

English Language Development and Differentiation

When forming groups, consider the needs of each student to develop groups with a variety of abilities and interests. Also, consider the student's English proficiency level. Grouping students with other speakers of their native language who are at different levels may be beneficial (3E).

Consider providing precut materials for the paper plate windmill for students who struggle with fine motor skills.

Teacher Note

These small windmills are typically called pinwheels. The key to creating a successful pinwheel is to have blades that bend enough to be pushed when students blow on them. Some students may need encouragement to bend the blades of their pinwheel more drastically to get the pinwheel to spin.

If some groups are finding success while others are struggling, it may help to have the class stop and allow students to share why they are stuck. Other students can share what modifications they made to create a pinwheel that spins (3E).

Share that the miniature windmills are a great way to demonstrate how wind can move objects. Ask students to respond to the following question in their Science Logbooks (Lesson 1 Activity Guide).

▶ What could you do if you harnessed the wind?

- *Maybe I could harness wind to sweep the floor. Could the wind do my chores?*
- *I could ride in a sailboat to an island.*

Check for Understanding

As students work, look for responses that describe how harnessing the wind allows something (usually work) to be done more easily.

Evidence

Look for evidence of understanding that people can use the wind to make life easier. Many ideas will be presented, from unrealistic to useful and from simple to complex.

Next Steps

Use student responses to inform the Lesson 2 Launch. If students have difficulty coming up with an idea, suggest the following sentence frame: If I could harness the wind, I would _______.

Optional Homework

Ask students to look for examples of where people have harnessed the wind to do something useful in their neighborhood or home.

Teacher Note

Energy is commonly referred to as the ability to do work, and this idea may arise during classroom discussions. However, during this module, students develop a basic understanding of energy without defining *work*.

Work is defined as the energy transferred when a force moves an object over a distance in the same direction as the force.

Lesson 2

Objective: Create a model windmill that generates electricity.

Agenda

Launch (5 minutes)

Learn (30 minutes)

- Introduce and Discuss *The Boy Who Harnessed the Wind* (10 minutes)
- Construct Physical Models (20 minutes)

Land (10 minutes)

Launch 5 minutes

Invite students to share their responses to Lesson 1's Check for Understanding question (What could you do if you harnessed the wind?) using a collaborative conversation routine, such as a Whip Around. Ask several students to elaborate by sharing why it might help to harness the wind in their chosen scenario; the goal is to reveal that harnessing the wind means to use wind power to make life easier.

Share with students that people had the idea that wind could make life easier hundreds of years ago when they designed the first windmills. Some early examples of such windmills were depicted in the Mondrian paintings students examined. Explain that people later learned how to use windmills to save lives. To learn how this is possible, students will continue exploring the Phenomenon Question **How do windmills harness the wind?**

Extension

If students completed the Optional Homework from the previous lesson, consider opening this Launch by asking students to share any examples they found. This will create a natural bridge from the previous day's learning to the next.

Teacher Note

The Whip Around collaborative conversation routine gives each student an opportunity to share their response to a question. Consider having all students stand until they share. As students share, any students with similar responses can sit down or use another signal to indicate their response. For more information, see the Instructional Routines section of the Implementation Guide (3E).

Learn 30 minutes

Introduce and Discuss *The Boy Who Harnessed the Wind* 10 minutes

Share the maps of the continent of Africa and the country of Malawi (http://phdsci.link/1158). Explain that Malawi is heavily populated but one of the world's poorest countries. The country is less developed economically than most others, with little industry and limited money invested in education and health care. Ninety percent of the population lives in rural areas, so agriculture is very important to people and the economy.

Ask questions to help students better understand life in a less developed country.

▶ **Based on what you know about the country, what types of challenges do you think people may face in Malawi?**

- *They might not have enough food or water for everyone.*
- *Kids may not be able to go to school. They may have to work to help their families get money for food.*
- *They may not have electricity if it is a poor country.*

Share with students that only 1 in 11 people in Malawi have access to electricity (World Bank 2018).

▶ **Since most people in Malawi do not have electricity, what else might they not have access to?**

- *They probably don't have lights.*
- *I bet they don't have phones or TVs like lots of us do.*

▶ **What would happen if this country were to experience a drought?**

- *There might not be food.*
- *All the plants would die and then they won't have any food or money.*
- *They might get sick without water to drink.*

Introduce students to *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010). Ask students to consider the following question as they listen to the beginning of the book: What steps will the boy take to help save his village by harnessing the wind? Read aloud the first part of the book through page 12. Stop reading after the sentence, "Windmills can produce electricity and pump water."

Lead a discussion with text-dependent questions such as the one that follows. As needed, reread relevant pages as students discuss their responses with a partner in a Think–Pair–Share.

▶ **In the last sentence, William wants to catch "magic." What "magic" do you think William is hoping to catch, and how will it help his family?**

- *William thinks the wind is magic because it will help his family get electricity and water.*

Teacher Note

The Boy Who Harnessed the Wind does not contain page numbers. Pages 1 and 2 referenced in this module show the illustration of William holding a tool over his shoulder and text that begins, "In a small village in Malawi …" Consider writing small page numbers in the text for reference.

Teacher Note

Think–Pair–Share is a collaborative conversation routine that allows students to share their response with a peer before sharing with the class (3E).

▶ What steps will William need to take to save his village by harnessing the wind?

- *He will need to find out where it is windy.*
- *He will need to learn a lot about how machines work.*
- *He will need to learn how a windmill harnesses the wind.*

Explain that William researched windmills at a library before building one in his village. Students now begin their own investigation into how windmills harness the wind by constructing physical models of windmills.

Construct Physical Models 20 minutes

Ask students to brainstorm the types of materials they would need to construct a windmill that generates electricity. Prompt them to think about what they know about electricity and what components electrical objects usually have. Students can record their ideas on personal whiteboards before sharing with the class.

Sample student responses:

- *We need fan blades and something tall for the base, like in the pictures.*
- *We need something to connect to the windmill, like a light or something that we can plug in to see if we have electricity.*
- *We might need wires or cords to connect the electricity.*

Explain that students will have access to kits that contain many of the materials mentioned, and they will work in groups to build physical models of windmills that generate electricity.

Pass out windmill model materials to each group and explain that the goal is to make the light-emitting diode (LED) light up. Encourage students to assemble the materials in different configurations to achieve this goal. See Windmill Model Setup Instructions (Lesson 2 Resource) for photographs of materials and proper windmill configuration.

Teacher Note

The size of these small groups will vary depending on class size. During materials preparation, determine how many groups you can support, and use that to select a grouping method that works best for your classroom.

Teacher Note

Students may need the following guidance when constructing their models (3E).

- The generator is a necessary part of the model. Allow students time to problem solve, but if they don't use the generator, guide them to use it.
- Explain that LEDs must be connected to the generator in a specific orientation (due to polarity). If the wires are reversed or do not form a complete circuit, the LED will not light up.

As students work, guide them to discuss and explore how and where the different components and wires connect. Once students develop a working model, introduce the term *complete circuit.*

▸ What do you think the arrows on the LED mean?

- *I think this is the path the electricity moves.*

Have students trace the complete circuit using their fingers.

Check for Understanding

As students develop their models, look for evidence of an early understanding of how the windmills work.

Evidence

Look for evidence that all students

- understand that the windmill's structure allows the blades to turn, and
- determine that wires (or cords) connect the windmill to the LED to allow electricity to flow.

Next Steps

Allow groups with a firm grasp on how to set up the windmill assist groups that have difficulty completing the task. Review each part of the windmill and ask students what they think the purpose of each part is and how it should connect to the other parts.

Land 10 minutes

Remind students of the Phenomenon Question **How do windmills harness the wind?** Ask students to draw a model in their Science Logbooks (Lesson 2 Activity Guide) to show how their physical model windmills harness the wind (i.e., use the wind to make something happen). Creating individual models will give students time to process their knowledge before sharing with the group. Next, students compare their drawings with those of other group members, revising their models and agreeing on a group model.

Content Area Connection: English

Use the word *circuit* to explore the Latin root *circ-*, which often means "around." Students brainstorm related words, such as *circle*, *circumference*, *circulate*, *circuitous*, and *circumstance*, and discuss how their meanings relate to the root. Challenge students to create sentences using *circuit* in both scientific and everyday contexts.

Teacher Note

To prepare students to investigate speed in a later lesson, check that students notice the correlation between the LED's brightness and the strength of the wind applied or the speed of the moving blades. If needed, follow up by asking more specific questions, such as What changes when the wind blows harder?

Differentiation

For students with graphomotor difficulties, consider providing pictures of different windmill parts and allowing students to glue them in their Science Logbooks, add labels, and explain their work.

When groups finish their models, ask students to share them with a partner from a different group. Students discuss similarities and differences between their models and record them in their Science Logbooks (Lesson 2 Activity Guide). Students may revise their models with any key components their partner shared with them.

To conclude the lesson, revisit the story of *The Boy Who Harnessed the Wind* and discuss how a windmill might help William.

▸ How might building a windmill in William's village help his family get food?
- *Electricity will help William pump water to the farms from far away.*
- *They might be able to use electricity to dig a deep hole and pump up water from the ground.*

Tell students that they will continue to learn how windmills can harness the wind and make life easier.

Optional Homework

Remind students that it is everyone's responsibility to conserve energy. Ask students to work with someone at home to examine how they use energy and create a list of ways to conserve it. Students should consider actions such as turning off lights that are not in use, turning the air conditioner to a warmer temperature in summer months and the heater to a cooler temperature in winter months, or walking, riding bikes, or taking buses to school and work instead of driving.

Lesson 3

Objective: Ask questions about energy.

Launch 2 minutes

Share the modern wind turbine photograph (Lesson 3 Resource A).

▶ **Have any of you seen a machine like this in real life? If you have, how tall do you think it was?**

Allow students to share their responses and then tell them that the machine in the photograph is called a *wind turbine*. Wind turbines work just like windmills—they use the wind to make something happen. Wind turbines in the United States are about 100 meters (or 328 feet) tall on average, which is the height of a 30-story building. Compare the size of the wind turbine to the size of their school building.

Agenda

Launch (2 minutes)

Learn (38 minutes)

- Notice and Wonder about Wind Farms (5 minutes)
- Develop an Anchor Model (13 minutes)
- Build a Driving Question Board (20 minutes)

Land (5 minutes)

Content Area Connection: Mathematics

Use this opportunity to apply metric unit conversions learned in mathematics. Consider asking students to convert 100 meters to centimeters or kilometers.

Review the Phenomenon Question **How do windmills harness the wind?**

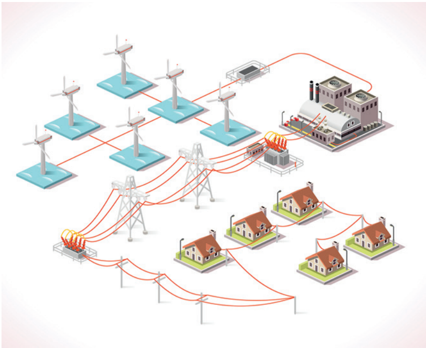
- ▶ What do you think this wind turbine is designed to do?
  - *The old-fashioned windmills harness the wind to grind wheat, but I don't think this wind turbine does that.*
  - *We made a model windmill that turned on a light. Maybe this wind turbine is sending electricity to the farm in the picture.*

To better understand how wind turbines work, explain that students will gather information about wind farms to help them add details to the windmill models they drew.

Learn 38 minutes

Notice and Wonder about Wind Farms 5 minutes

Display the wind farm photograph and wind farm diagram (Lesson 3 Resources B and C).



Ask students to notice and wonder about what they see in the two images and record their thoughts in their Science Logbooks (Lesson 3 Activity Guide) before sharing with the class.

Teacher Note

Encourage students to use words such as *transfer*, *transport*, *carry*, *travel*, *flow*, and *path* to describe how energy or electricity gets from the wind turbines to the houses. Use of scientific terminology will help students accurately describe their findings as they explore electricity in future lessons.

▶ What do you notice about the photograph of the wind farm?

- *There are a lot of wind turbines out in the water.*
- *The wind turbines are tall and skinny in both pictures. Even the blades are skinny.*
- *Two cords or pipes are coming out of the water. Or maybe they are going in.*

▶ What do you notice about the diagram of the wind farm?

- *The red lines connect the wind farm to houses. They go through other things in the middle.*
- *I think those are power lines. We have power lines where I live. When they stop working, our lights go off.*

▶ What do you wonder about these two pictures?

- *In the diagram, does electricity flow through all the wires?*
- *What are those black cords in the photograph?*
- *Why don't they have houses attached to them like those paintings we looked at?*
- *What do these wind turbines do? How do they make electricity?*

Tell students that the black cord in the photograph connects the wind farm, or group of wind turbines, to other places. In the diagram, the wind farm connects to houses. Students will use what they noticed about the wires as they use the models they drew in Lesson 2 to develop a class anchor model.

Develop an Anchor Model 13 minutes

Invite students to review their windmill models from Lesson 2 and consider the wind farm images to develop a class anchor model. Ask students to share their models by naming the specific parts they drew, and encourage them to identify common components across models. As students agree on certain components, draw them on chart paper to develop a class anchor model. Title the model and include an explanation.

Ask students to consider whether anything is missing from the anchor model.

Sample student responses:

- *My partner and I both drew the windmill with a stick and a fan on top.*
- *I drew a light.*

Teacher Note

This initial anchor model serves as a point of reference throughout the module. As students uncover more about energy and how it behaves, they will update this model to reflect their deepening understanding (4C).

- *We had a light, too, with wires going into it.*
- *My partner showed the wind, but I forgot. So, I added it to my model.*

As students share new components to add to the anchor model, ask the rest of the class to use nonverbal signals to indicate whether they agree that the new component accurately shows how the windmill works. Call on students to justify their agreement or disagreement with evidence from their observations of the physical model. As needed, ask additional questions to help students build on the ideas of others and express their own ideas clearly.

Sample student responses:

- *I agree with drawing an arrow from the windmill blades to the lights. I think electricity for the light comes from the wind. In the physical model, the light only came on when the wind blew and the blades turned.*
- *I disagree with drawing that arrow because I think it should go along the wires. The bulb didn't light up without wires, so I think the electricity is moving through the wires.*

If most students agree with adding a component and can justify its inclusion, draw it on the anchor model. As the anchor model develops, encourage students to revise the drawing in their Science Logbooks.

Check for Understanding

As the class develops the anchor model, check for understanding that the windmill harnesses the wind and that wires play an essential role in transforming wind into light.

Evidence

Listen for students to suggest the following critical components:

- Wind moving the blades of the windmill
- Wires connecting the windmill to the light
- Light turning on

Next Steps

Students should understand that energy (wind) is necessary to make something happen (LED light up). If students do not suggest adding the above components to the anchor model, revisit the physical models they constructed in Lesson 2.

Anchor models will vary for each class, but most should include these components: windmill blades, wind, a light, and wires.

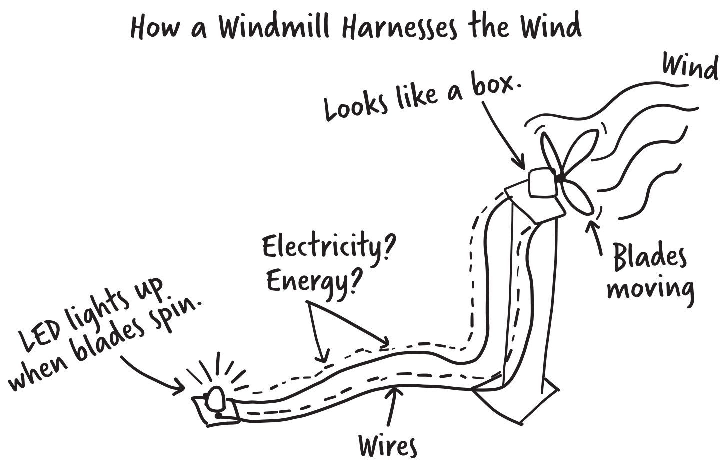
Content Area Connection: English

In discussions, use additional questions and sentence frames to help students meet grade-level expectations for speaking and listening. For example, the sentence frame "I agree (or disagree) with _______ because _______" can help students link their comments to others' ideas. In addition, students can ask the follow-up question "What evidence supports that idea?" to help peers explicitly cite and interpret evidence relevant to the topic of discussion (3C).

Depending on the conversation, anchor models may also include these other components:

- A generator (shown as an unidentified box)
- Arrows or other indicators to show the spinning motion of the blades
- Arrows or lines in or around the wires to represent the movement of energy or electricity
- A representation of sound coming from the blades

Sample anchor model:



Wind moves the blades of the windmill, which are attached to something that looks like a box. Energy moves through the wires and turns on the light.

If the anchor model does not include the word *energy*, ask the following question:

▶ What could be moving through the wires?

- *Electricity. Lights need electricity to turn on.*
- *Power. The wind has power that moves through the blades and the wires to the light.*

Tell students they can also use the term *energy*. Explain that **energy** is necessary to make something happen. Students will explore energy throughout the module to explain phenomena such as windmills turning on lights or grinding wheat.

Teacher Note

Students may use the word *power*, but power and energy are not the same. Power is the rate at which work is done or energy is transferred. Power is not discussed in this module. Encourage students to use the word *energy*.

Teacher Note

If students struggle to identify the presence of energy as the common factor, press students to share why the wind helps in each of their examples. Discuss how each example demonstrates how wind can help make people's lives easier by doing work for them. Draw this back to the usefulness of wind by asking, Where did that extra energy come from?

English Language Development

The term *energy* is central to this module. Introduce this term explicitly, using the process outlined in the English Language Development section of the Implementation Guide. The Spanish cognate *energía* and related English words such as *energetic* may be useful. As with other important words, scaffolds such as oral rehearsal and sentence frames may benefit some English learners throughout the module as they use the term *energy* in speaking and writing. Some students may benefit from explicit instruction of the term *place* in this lesson, as well.

When students understand that energy is present in the windmill system, have them quickly reflect in their Science Logbooks (Lesson 3 Activity Guide) on the question that follows.

▶ What is energy?

Check for Understanding

This task is a pre-assessment. Use responses to assess students' developing understanding of the Focus Question **What is Energy?**

Evidence

Look for evidence in student responses of understanding of the following concepts:

- Energy can help us do different activities, such as running, walking, and playing sports.
- There are different kinds of energy, such as motion and electricity.

Next Steps

Throughout the module, students work to deepen their understanding of energy (i.e., how to describe it and how it behaves). Use these initial responses as a point of reference throughout the module to reflect informally on students' growing understanding of energy.

Build a Driving Question Board 20 minutes

Acknowledge that students may have many questions about the windmill phenomenon and the concept of energy. Invite them to write their questions about energy in their Science Logbooks (Lesson 3 Activity Guide). Next, students choose at least one question they are most interested in and write it on a sticky note.

Differentiation

Students who have difficulty with writing can answer questions orally with someone scribing their answers for them, or orally writing only one key point.

Teacher Note

As students record these questions, encourage students to mark any particularly revealing questions with a star. Students will later draw from these questions to develop the driving question board for the module.

Differentiation

Some students may struggle to come up with questions about energy. If needed, post pictures around the classroom of windmills and models from previous lessons as a visual reminder of students' experiences with energy thus far.

Tell the class they will use their questions to develop a driving question board. Explain that this driving question board will serve as a point of reference throughout the module as they seek to answer their questions about windmills and energy.

Display the driving question board and write (or reveal) the Essential Question **How do windmills change wind to light?** on the board. Explain that this question will help students focus their studies of wind and energy.

Have students share the questions on their sticky notes. After one student reads a question and places it on the driving question board, invite students who think they have a related question to read theirs and place it next to that question on the driving question board. Throughout the discussion, ask follow-up questions or make suggestions to help students group their questions. Guide the grouping toward the three categories listed below. When students have finished posting their questions, work together to develop and post the Focus Question for each category on the driving question board.

Concept 1 Focus Question: **What is energy?**

Related student questions may include the following:

- *What is energy?*
- *What is electricity?*
- *What does energy look like?*

Concept 2 Focus Question: **How does energy transfer from place to place?**

Related student questions may include the following:

- *What do the wires do?*
- *How do people get energy when there is no wind?*
- *How could people get more energy from the windmills?*

Concept 3 Focus Question: **How does energy transform?**

Related student questions may include the following:

- *How does a windmill make electricity?*
- *How can wind change to light?*

Differentiation

If needed, differentiate how students share or group their questions. In smaller classes, students may write more than one question to provide enough questions. With English learners or below-grade-level writers, consider writing students' questions for them as the class shares. For groups reluctant to share questions, students may read each other's questions anonymously.

Teacher Note

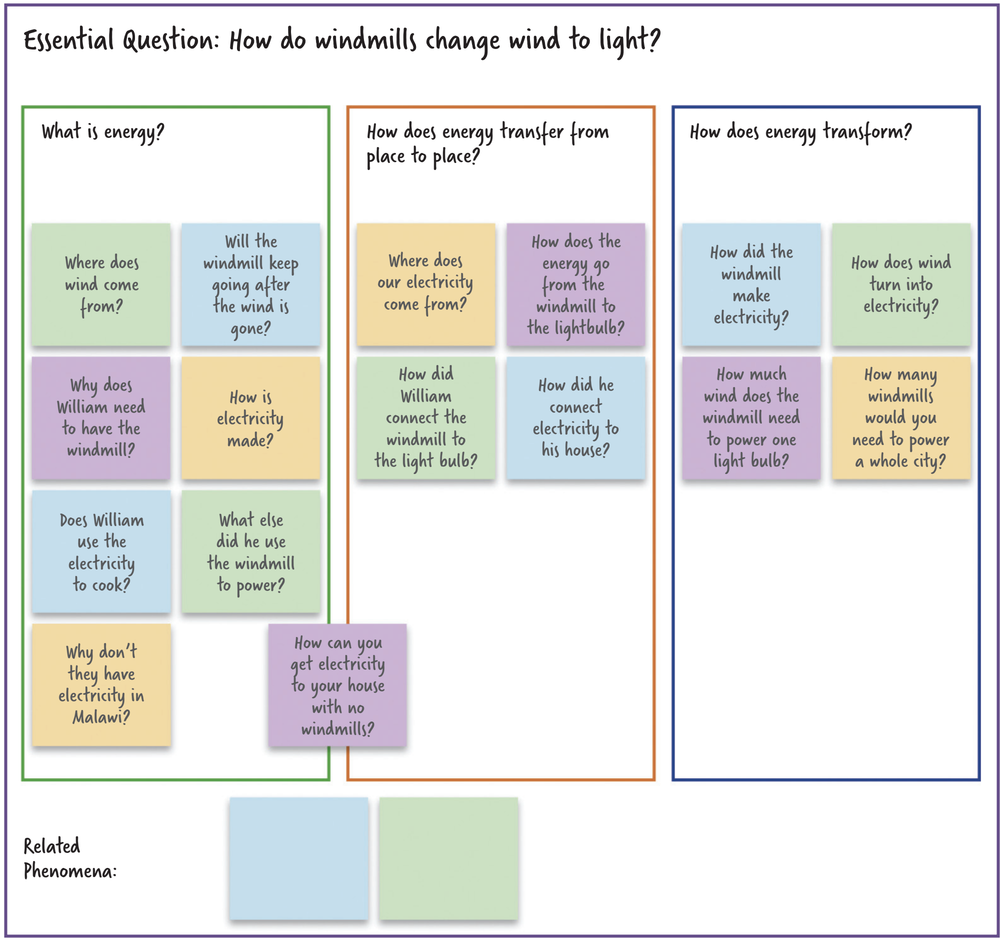
Write down the focus questions and keep the list available for reference during this discussion. As students post their questions, offer occasional guidance to ensure that students group the questions in a way that can later be summarized under each focus question (4C).

Teacher Note

Each category on the driving question board relates to the Focus Questions that guide upcoming lessons.
In Lessons 1–5, students explore defining and categorizing energy indicators with the Focus Question **What is energy?**
In Lessons 6–9, students explore the next Focus Question: **How does energy transfer from place to place?**
In Lessons 10–14, students explore the final Focus Question: **How does energy transform?** (4C).

Keep the driving question board posted in a public place that makes it easy to update and revisit throughout the module. It may also help to allow for space to post associated sample student products along the way.

Sample driving question board:



To get students to think more deeply about the anchor phenomenon, ask students to share related, familiar phenomena. Use the following question to draw out student knowledge.

Spotlight on Knowledge and Skills

As students continue to practice asking questions for investigation, the focus and relevance of their questions should improve. Be sure to discuss which questions will lead to a deeper understanding of how a phenomenon works and provide suggestions to further refine the focus and relevance of students' questions.

Teacher Note

If students were assigned the Optional Homework in Lesson 1, ask students to consider their responses as they generate related phenomena.

▶ When have you experienced or heard of something harnessing the wind?

- *When it is hot outside, I can make a paper fan and use it to cool myself.*
- *I can fold paper and throw it to make a paper airplane.*
- *I have a fan in my bedroom at home, and it blows air to cool me down.*

Summarize relevant student responses at the bottom of the driving question board in a section labeled *Related Phenomena*. As students describe related phenomena throughout the module, add them here.

Land 5 minutes

Instruct students to record the Essential Question in the Module Question Log of their Science Logbooks.

Draw students' attention to the driving question board and ask them to consider which category would be the best place to begin. If necessary, guide students to choose the Concept 1 Focus Question, **What is energy?**, with prompts such as Which of these questions would help answer the other two questions?

Have students summarize what they have learned so far about windmills by building their own. Review the anchor model for extra support as needed.

Sample student response:

- *Wind moves the blades, something that looks like a box sends energy through the wires to a light, and the light comes on.*

Tell students that over the next few lessons they will explore the Focus Question for the first concept: **What is energy?**

Optional Homework

Students identify one example of energy being used in their home or neighborhood and draw a model to represent its use.

Lessons 4–5
Energy Indicators

Prepare

To begin investigating their questions from Lessons 1–3, students explore the Concept 1 Focus Question **What is energy?** Students then visit Energy Stations to explore energy-related phenomena, including light, sound, heat, motion, and electrical energy. In these stations, students observe patterns and identify indicators of the presence of energy. They use these indicators as evidence that energy is present.

Student Learning

Knowledge Statement

Light, sound, temperature change, and motion indicate the presence of energy in a system.

Objectives

- Lesson 4: Observe indicators of the presence of energy.
- Lesson 5: Classify indicators of the presence of energy.

Concept 1: Energy and Its Classifications

Focus Question

What is energy?

Phenomenon Question

How do we know energy is present?

Texas Essential Knowledge and Skills Addressed

4.2D Analyze data and **interpret patterns to construct reasonable explanations from data that can be observed** and measured. (Addressed)

4.2F **Communicate valid oral and written results** supported by data. (Addressed)

4.3B **Represent the natural world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)

4.6A **Differentiate among forms of energy, including mechanical, sound, electrical, light, and thermal.** (Addressed)

English Language Proficiency Standards Addressed

1E Internalize new basic and academic language by using and reusing it in meaningful ways in speaking and writing activities that build concept and language attainment.

4C Develop basic sight vocabulary, derive meaning of environmental print, and comprehend English vocabulary and language structures used routinely in written classroom materials.

5G Narrate, describe, and explain with increasing specificity and detail to fulfill content area writing needs as more English is acquired.

Materials

		Lesson 4	Lesson 5
Student	Science Logbook (Module Question Log)	●	
	Science Logbook (Lesson 4 Activity Guide)	●	●
	Science Logbook (Lesson 5 Activity Guide)		●
Teacher	Energy Stations (2 per station): hand-crank flashlight, pull back cars, portable radio with batteries, Snap Circuits® Green kit windmill (assembled), heat lamp, block of wood, sandpaper	●	●
	Sentence strips		●
Preparation	Set up Energy Stations.	●	●

Lesson 4

Objective: Observe indicators of the presence of energy.

Agenda

Launch (5 minutes)

Learn (35 minutes)

- Observe Energy Stations (35 minutes)

Land (5 minutes)

Launch 5 minutes

Remind students of the Concept 1 Focus Question **What is energy?** Explain that, in this lesson, they will visit several stations to learn more about the nature of energy. Reveal the Phenomenon Question for Lessons 4 and 5: **How do we know energy is present?** Ask students to record this Phenomenon Question in their Module Question Logs.

▶ How might you know when energy is present?

- *Energy is what people and other things need in order to move.*
- *If we see something move or we see something causing something to move, energy is present.*
- *A phone screen has energy when it lights up. If something is making light, it has energy.*
- *Energy comes from electrical outlets and batteries. Electricity can make things move or turn on.*

Use students' ideas to post a short description of how people know when energy is present.

Sample description:

We think energy is present when something moves or happens.

Ask students to keep this description in mind as they visit different Energy Stations to see if it accurately describes what they observe.

Differentiation

The word *present* can have multiple meanings, so it may help to discuss with students the meaning of the word in this context. Challenge students to come up with other ways to ask this question such as How might we know when energy is in a particular place?

Learn 35 minutes

Observe Energy Stations 35 minutes

Divide the class into six groups. Groups will rotate through each of six Energy Stations. The order of the stations does not matter, but students should spend about 5 minutes at each station. Set a timer to maintain an appropriate pace. Students should explore the materials at each station, look for evidence of the presence of energy, and record observations in their Science Logbooks (Lesson 4 Activity Guide). Remind students to record observations that can help them answer the question in their logbooks: What do you observe at each station that indicates (or shows) the presence of energy?

Students visit the following Energy Stations:

- Station 1: Hand-crank flashlight
- Station 2: Pull back cars
- Station 3: Portable radio with batteries (Remove batteries from the radio as students change stations. Students should put in the batteries to make the radio work when they get to the station.)
- Station 4: Snap Circuits® windmill (assembled)
- Station 5: Heat lamp (Disconnect plug as students change stations. Students should connect the plug when they get to the station.)
- Station 6: Wood block with sandpaper

Safety Note

The Heat Lamp Station poses potential hazards. Explain that heat lamps may cause burns or eye damage and electrical outlets and cords may cause electric shock. To minimize the risk, review these safety measures and look for evidence that students are following them (4.1A):

- Do not touch any part of the heat lamp except the electrical cord and plug.
- Do not look directly into the lamp when it is turned on.
- Do not stick fingers or other objects in the electrical outlet.
- Remove an electrical plug from an outlet by pulling the plug, not the cord.

Teacher Note

Students should not be given directions on what to do at each Energy Station. Instead, allow students to explore energy on their own. Each station should include two of each of the listed materials. No other setup is required.

Differentiation

The time at each station is limited to 5 minutes, but some students may need extra time. Adjust time as needed to ensure that students build an understanding of indicators of energy.

Students work at each station for 5 minutes to explore energy and record observations. As students work, circulate to support teamwork and promote detailed recording in their Science Logbooks with prompts such as these: What indicators of energy did you observe? What senses did you use? What patterns did you observe?

Sample student responses:

- *(Station 1: Hand-crank flashlight) When I spin the crank on the flashlight, the light comes on. I noticed a pattern: the faster I turned the crank, the brighter the light was.*
- *(Station 2: Pull back cars) Sometimes the cars moved slowly, and sometimes they moved quickly. When I pulled the car back far, it rolled far. When the two cars crashed, they made a noise. The second car moved when the first car hit it.*
- *(Station 3: Portable radio with batteries) When I put the batteries in and pushed the power button, sound came out of the radio. When I pushed the button again, sound stopped. It's a pattern. When I took the batteries out, the pattern changed. The radio didn't turn on at all.*
- *(Station 4: Snap Circuits® windmill) The light turned on when the windmill blades moved and turned off when the spinning stopped. When I blew harder, the light got brighter.*
- *(Station 5: Heat lamp) The lamp started to get hot when I put the plug into the outlet. The air around the lamp got hot, even though I wasn't touching it. When I unplugged the lamp, the air started to cool.*
- *(Station 6: Wood block and sandpaper) After I rubbed the sandpaper on the block, the block was hot. The faster I moved the sandpaper, the hotter the block got.*

Check for Understanding

Use student responses as an opportunity for informal assessment of student understanding of energy.

Evidence

Look for students to record

- what they noticed about energy at the stations, and
- examples of the indicators of energy they observed.

Next Steps

If students struggle to record meaningful observations, provide guidance as needed. For example, use a prompt such as What did you observe that made you think energy was present?

Content Area Connection: Mathematics

As students record observations, guide them to use specific language and estimation. Listen and look for complex comparative phrases (e.g., "twice as much as … ") and for units of measurement (e.g., centimeters, inches). For example, a student might notice that a car that is pulled back 10 centimeters travels twice as far as a car pulled back 5 centimeters.

English Language Development

Speaking and writing about these observations involves complex sentence structure and precise language, such as use of the word *energy*. English learners may benefit from additional scaffolding in the form of sentence frames such as the following (5G):

- _______ needs energy to _______.
- When I _______ , then _______.

Differentiation

Consider providing premade drawings of the stations for students who need additional support. Students can identify what they observe and add their own explanations.

Land 5 minutes

Remind students that throughout the lesson, they have investigated the Phenomenon Question **How do we know energy is present?**

Ask students to revisit the observations they recorded in their Science Logbooks and circle or highlight anything that they believe indicates the presence of energy in each system. Model this process with a student sample to clarify.

Sample student response:

- *When I spin the crank on the flashlight, the light comes on.*

Explain that when identifying indicators, students should try to limit their ideas to a single word or a short phrase that shows evidence of energy. If needed, coach students to correctly identify indicators with prompts such as these: Why did you write this observation? What made you think that energy was present? In what you circled, what is the indicator of energy, and how can you narrow that to a word or two? Students share their observations in the next lesson.

Optional Homework

Students share what they learned at the Energy Stations with their families at home. Encourage them to find household objects to set up stations for family members and discuss the energy indicators they observe.

Differentiation

Students may not be familiar with the terms *indicate* or *indicator*. Discuss some other common indicators in everyday life, such as a car's fuel light as an indicator of low fuel, snow as an indicator that it is cold outside, or a snake's bright colors as an indicator that it may be poisonous (1E).

Lesson 5

Objective: Classify indicators of the presence of energy.

Agenda

Launch (5 minutes)

Learn (33 minutes)

- Identify Examples of Energy (15 minutes)
- Classify Energy Indicators (13 minutes)
- Conceptual Checkpoint (5 minutes)

Land (7 minutes)

Launch 5 minutes

Review the Phenomenon Question **How do we know energy is present?**

Ask students to discuss the following questions with a partner, drawing on their observations in the previous lesson (Lesson 4 Activity Guide).

▶ What examples of energy did you observe?

- *The pull back cars had energy. When I pulled them back, they moved fast.*
- *When I turned the flashlight crank and the light came on, I was using energy to turn the crank. I think the light was energy, too.*

▶ What patterns did you notice across different examples?

- *I used my senses at all the stations. I saw light, heard sound, and felt hot air.*
- *Things moved at most stations. The cars, flashlight crank, windmill blades, and sandpaper all moved.*

Tell students that because they observed so many differences in examples of energy, they will look for more patterns across their observations in this lesson.

Learn 33 minutes

Identify Examples of Energy 15 minutes

Ask students to share the indicators of energy they observed within the systems at each Energy Station and to explain, using evidence, why they thought energy was present. Remind students that energy is present when something happens (e.g., when an object moves, gets hotter, lights up, or makes a sound) and when something is required (e.g., electricity, muscles, batteries) to make something else happen.

As students provide examples and evidence, record each statement on a sentence strip.

Sample student responses:

- *Station 1: Hand-crank flashlight*
  - *When I turned the handle on the flashlight, the light turned on.*
- *Station 2: Pull back cars*
  - *When I pulled back on the car, it moved and made a sound.*
- *Station 3: Portable radio with batteries*
  - *When I put in the batteries and turned on the radio, music played.*
- *Station 4: Windmill model*
  - *When I blew on the windmill blades, the light turned on.*
- *Station 5: Heat lamp*
  - *When I plugged in the heat lamp, the air around it got warmer.*
- *Station 6: Wood block and sandpaper*
  - *The faster I rubbed the sandpaper across the wood block, the warmer the block got.*

If students overlook important examples of energy, prompt with questions such as these: You observed sound with the radio; did you observe sound at any other stations? What happened when you removed the radio batteries?

Classify Energy Indicators 13 minutes

After students share all of their examples of energy, begin to classify the examples.

- ▶ Which examples have something in common?
- ▶ What patterns do you notice that connect some examples?
- ▶ What could we call each group?

Spotlight on Knowledge and Skills

Although naming the forms of energy may help students discuss the concepts of energy transfer and transformation with more confidence in later lessons, their use of precise terminology at this point is not the goal of instruction.

Teacher Note

It is likely that students will use the word *heat* to discuss the presence of thermal energy in stations 5 and 6. *Heat* has many meanings in everyday language, but in science, *heat* has a very specific meaning: *Heat* is the transfer of energy from something warmer to something cooler (1E).

Through classroom discussions, model appropriate terminology. For example, students feel a temperature change in stations 5 and 6; they do not feel heat.

Differentiation

As needed, demonstrate how the objects from the stations work, or invite students to revisit the stations to gather their own evidence.

As students share their ideas, arrange the sentence strips with their responses into categories and label each category.

Sample categories:

- *Light: flashlight shines, LED lights up, light gets brighter*
- *Motion of objects: crank moves, car moves, blades spin, sandpaper rubs, object moves faster*
- *Temperature change: object gets hot, heats up, cools down*
- *Sound: music plays, wheels turn, cars crash*
- *Other: electricity, outlet, batteries, muscles*

Explain that it can be useful to classify **indicators of energy** into categories, such as sound, light, temperature change, motion of objects, and other indicators. Use these categories to update the description developed in Lesson 4 of how people know when energy is present.

English Language Development

Introduce the word *indicator* explicitly, using the process outlined in the English Language Development section of the Implementation Guide. Break *indicator* into the verb *indicate* and suffix *-or* and explore the Latin roots *indic-* and *-ate*. Discuss the meanings of *indicator* in different contexts, such as an indicator light on a dashboard. Sharing the Spanish cognate *indicar* may also be helpful.

Additionally, English learners may benefit from explicit introduction of other words in this lesson, such as *object*, *temperature*, *light*, *sound*, and *electricity*. Some students may also benefit from explicit introduction of the verb *move*.

Begin an anchor chart to record students' knowledge of energy. Leave space for the class to add new knowledge in future lessons. Post the chart near the driving question board and anchor model so students can refer to all three visuals throughout the module. Have students add the indicators of energy to the anchor chart.

Differentiation

Some students may benefit from arranging their own sentence strips with energy examples, rather than watching someone else arrange sentence strips. Ask these students to copy the examples from sentence strips onto sticky notes, with one example per sticky note. Students can then manipulate the sticky notes to develop their own categories (5G).

Teacher Note

Although students cannot observe the presence of energy in electricity, batteries, and muscles, they should intrinsically know that energy is present.

At this point, students may not understand that electric current flows in wires from the wall, through the cord, and to the heat lamp, or that batteries and muscles store potential energy until it is needed. Students should not be expected to understand potential (or stored) energy, but they should see batteries as a source of energy.

Teacher Note

Consider recording information for the anchor chart in a way that is easy to reposition so that the class can revise and reorganize the chart as students' thinking develops throughout the module. Some options are writing on sentence strips taped to the chart, writing on papers that stick to the chart with removable glue, or creating a digital chart (4C).

Sample anchor chart:

Energy
Energy is present when we observe something happening (moving objects, light, temperature change, sound) or when something helps make something happen (electricity, batteries).

Conceptual Checkpoint 5 minutes

Ask students to use their new knowledge to write a response to the following question in their Science Logbooks (Lesson 5 Activity Guide).

▶ What would our classroom be like if there were no energy?

Conceptual Checkpoint

This Conceptual Checkpoint assesses student understanding of the Concept 1 Focus Question **What is energy?** Students should demonstrate understanding of energy indicators in their responses.

Evidence

Student responses will vary, but look for evidence that they understand that without energy, the classroom would not have any indicators of energy (e.g., light, temperature change, motion, electricity, sound, or even batteries).

Next Steps

If students do not discuss missing indicators of energy in their responses, have them revisit the Energy Stations.

Land 7 minutes

Ask students to use their observations of energy to reflect on the Concept 1 Focus Question **What is energy?** Work with students to develop a description and add it to the top of the anchor chart. Acknowledge that energy is difficult to define, but it helps people understand how things happen.

Differentiation

If students need support on this Conceptual Checkpoint, scaffold by asking similar questions that relate to the stations they visited.

- What would happen if the crank broke on the flashlight?
- What if the radio did not have batteries?

Sample anchor chart:

Energy
Energy is why things happen.
Energy is present when we observe something happening (moving objects, light, temperature change, sound) or when something helps make something happen (electricity, batteries).

Ask students whether their new understanding of energy indicators helps answer any of their questions under the Concept 1 Focus Question **What is energy?** While students listen to their peers, they can use nonverbal signals to indicate if they agree or disagree.

Revisit the list of related phenomena at the bottom of the driving question board. Ask students to Think–Pair–Share about how their new learning about energy may explain these phenomena. Lead a discussion to help students make appropriate connections.

- ▶ At the Energy Stations, when did things seem to have more energy or less energy?
  - *The radio didn't make any sound without the battery, so I don't think it had energy without the battery.*
  - *I think the faster pull back cars had more energy than the slower ones.*
  - *When I cranked the flashlight quickly, the light was brighter. And when I blew hard on the windmill, the blades moved faster and the light was brighter. I think a brighter light has more energy than a dim light.*

Call attention to student responses that relate to speed, such as the speed of the windmill blades spinning, flashlight crank turning, cars moving, and sandpaper rubbing. Tell students that they may have found a pattern connecting speed and energy. Explain that if they can understand this relationship better, they may be able to harness more energy in certain situations.

In the next lesson, students will investigate the Phenomenon Question **What is the relationship between energy and speed?** Instruct students to record this question in the Module Question Log of their Science Logbooks.

Teacher Note

Using a different color for each addition to the anchor chart helps students keep track of new information (4C).

Teacher Note

Keep Energy Station materials on hand during this discussion to support student use of specific evidence related to speed and energy.

Teacher Note

In subsequent lessons, continue directing students to record new Phenomenon Questions in the Module Question Log.

Lessons 6–7
Effect of Energy on Speed

Prepare

In previous lessons, students developed a description of energy and identified indicators of its presence. In Lesson 6, students make a prediction about the relationship between energy and speed. They then explore this relationship with a range of classroom objects. In Lesson 7, students design a fair test investigation to manipulate the energy input of a system and take quantitative measurements to observe the cause and effect relationship between energy and speed.

Concept 2: Energy Transfer

Focus Question

How does energy transfer from place to place?

Phenomenon Question

What is the relationship between energy and speed?

Student Learning

Knowledge Statement

The speed of an object is related to the energy of the object.

Objectives

- Lesson 6: Describe the relationship between energy and speed.
- Lesson 7: Interpret data showing that greater energy input enables greater speed.

Texas Essential Knowledge and Skills Addressed

4.2A **Plan and implement descriptive investigations, including asking well defined questions, making inferences, and selecting and using appropriate equipment or technology to answer his/her questions.** (Addressed)

4.2B **Collect and record data by observing and measuring, using the metric system,** and using descriptive words and numerals such as labeled drawings, writing, and concept maps. (Addressed)

4.2C **Construct** simple tables, **charts**, bar graphs, and maps using tools and current technology **to organize, examine, and evaluate data**. (Addressed)

4.2D **Analyze data and interpret patterns to construct reasonable explanations from data that can be observed and measured.** (Addressed)

4.2F **Communicate** valid oral and written **results** supported by data. (Addressed)

4.3A **Analyze, evaluate, and critique scientific explanations by using evidence, logical reasoning, and experimental and observational testing.** (Addressed)

4.3B **Represent the** natural **world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)

4.4 **Collect, record, and analyze information using tools, including** calculators, microscopes, cameras, computers, hand lenses, metric rulers, Celsius thermometers, mirrors, spring scales, balances, graduated cylinders, beakers, hot plates, **meter sticks**, magnets, collecting nets, and **notebooks; timing devices;** and materials to support observation of habitats of organisms such as terrariums and aquariums. (Addressed)

4.6A **Differentiate among forms of energy, including mechanical,** sound, electrical, light, and thermal. (Addressed)

English Language Proficiency Standards Addressed

3B Expand and internalize initial English vocabulary by learning and using high-frequency English words necessary for identifying and describing people, places, and objects, by retelling simple stories and basic information represented or supported by pictures, and by learning and using routine language needed for classroom communication.

5F Write using a variety of grade-appropriate sentence lengths, patterns, and connecting words to combine phrases, clauses, and sentences in increasingly accurate ways as more English is acquired.

Materials

		Lesson 6	Lesson 7
Student	Science Logbook (Lesson 6 Activity Guide)	●	
	Science Logbook (Lesson 7 Activity Guide)		●
	Speed Investigation (per group): textbook (at least 1" thick; the same type or size for each group), ruler, 1" ball bearing, stopwatch, tape, meter stick		●
Teacher	Speed Station (2 per class): pull back cars; Snap Circuits® Green kit windmill (assembled); soccer ball, kickball, or another object based on class suggestion	●	
Preparation	Ensure that all stopwatches work properly.		●

Lesson 6

Objective: Describe the relationship between energy and speed.

Agenda

Launch (10 minutes)

Learn (25 minutes)

- Investigate Energy (20 minutes)
- Draw Initial Conclusions (5 minutes)

Land (10 minutes)

Launch 10 minutes

Pose the following scenario to the class, and allow students to share and discuss their responses.

▶ **Cars usually move at a speed of 60 miles per hour on the highway, but race cars move at speeds up to 200 miles per hour. So a trip that would take 20 minutes in a regular car might take only 6 minutes in a race car. Do you think this statement is correct?**

- *That would only happen if the race car were on a track with no stoplights or traffic.*
- *The race car is moving a lot faster, so I think that's correct. The trip would take less time for the race car.*

Have students write the Phenomenon Question at the top of the Lesson 6 Activity Guide to frame the investigation for this lesson: **What is the relationship between energy and speed?** Review student understanding of energy from previous lessons.

▶ What do we know so far about energy?

- *Energy helps make things happen.*
- *Energy can look different and do different things. Sometimes it is movement, a light shining, or even music playing.*

Ask students to work with a partner to make a prediction about the relationship between speed and energy and write it on a sticky note or individual whiteboard to share with the class.

Differentiation

Students may benefit from a discussion of the word *relationship* in other contexts to help them apply it to energy and speed. Have students practice describing the relationships between other pairs of words, such as *predator* and *prey*, *parent* and *child*, or *temperature* and *weather* (3B).

Have students who struggle with written language draw a picture to illustrate the relationship between energy and speed.

Sample student responses:

- *If I throw something hard, it will fly really fast and go really far.*
- *The more energy I give something, the faster it will move.*
- *An object that moves quickly has more energy than an object that moves slowly.*

Use student responses to record a class prediction on the board. Keep this prediction posted to revisit later in the lesson, and ask students to record it in their Science Logbooks.

Sample class prediction:

When we give an object more energy, it will move faster.

▶ How do you know when an object has more energy or less energy?

- *When I'm running around really fast, my mom says I have too much energy. Is that the same?*
- *I think we have to do more of something to give more energy to an object. Like at the hand-crank flashlight Energy Station, I had to spin the crank really fast to make the light brighter. I felt like I was doing a lot of work.*

Ask students to think about ways they could test the class prediction with the materials available to the class. Encourage students to consider the materials they used in previous lessons as well as other materials available to them inside the classroom. As a class, brainstorm a list of possible objects to test and write the ideas on the board. Work with students to select three objects they can use to test the class prediction, and then develop a class investigation plan. Have students record the investigation plan and which objects they will test in their Science Logbooks.

Teacher Note

In this lesson, students should deepen their understanding of how the amount of energy put into a system affects the speed of components in the system. Students may respond that faster-moving objects possess more energy. While these responses are valid, highlight those that focus on greater energy causing an object to move with more speed. The reverse relationship is studied in more detail in later levels.

Spotlight on Knowledge and Skills

At this point in the module, students may think that energy is "given" to an object. In Lesson 8, students clarify this understanding as they investigate transfer of energy. Students learn that energy moves by moving objects or through sound, light, heat, and electric currents.

Teacher Note

As students share ideas of objects to test, keep quantity in mind. Depending on class size, at least two sets of materials for each test (e.g., two sets of pull back cars, two windmills, and two soccer balls) may be required.

Sample investigation table:

Investigation Plan *Use a small amount of energy or a lot of energy to make the objects move and see how fast they go.*		
Object 1 *Pull back car*	**Object 2** *Windmill*	**Object 3** *Soccer ball*
Prediction *When we put more energy into the pull back cars by pulling them back more, they will move faster.*	**Prediction** *When we put more energy into the windmill by blowing more, the windmill blades will spin faster.*	**Prediction** *When we put more energy into the soccer ball by kicking it harder, it will move faster.*
Observations	**Observations**	**Observations**

Learn 25 minutes

Investigate Energy 20 minutes

Set up stations to test the chosen objects, and then divide students into groups for the investigation. Explain the importance of each member having a turn to conduct each test. Students then work in their groups to test the class predictions and determine whether there is a relationship between energy and speed. Have students fill out the Observations columns in their Science Logbooks as they investigate at each station.

Teacher Note

Ensure that the number of stations are adequate for each group to visit each station once in 15 minutes.

For example, in a class with 30 students, divide students into six groups of five and set up two stations for each test (e.g., two pull back car stations, two windmill stations, two soccer ball stations). Allow students to spend about 5 minutes at each station.

Content Area Connection: English

As students record observations, reinforce the skill of taking notes to help recall relevant information. Students can write phrases or complete sentences and should use precise language to objectively describe their observations.

Sample investigation plan:

Investigation Plan *Use a small amount of energy or a lot of energy to make the objects move and see how fast they go.*		
Object 1 *Pull back car*	**Object 2** *Windmill*	**Object 3** *Soccer ball*
Prediction *When we put more energy into the pull back cars by pulling them back more, they will move faster.*	**Prediction** *When we put more energy into the windmill by blowing more, the windmill blades will spin faster.*	**Prediction** *When we put more energy into the soccer ball by kicking it harder, it will move faster.*
Observations *When we pull the car back more, it goes faster (more speed). When we pull it back less, it moves slowly (less speed). When we pull the car back more, we are giving it more energy because we are using our muscles to pull it back.*	**Observations** *When we blow softly, the windmill blades spin slowly (less speed). When we blow harder, the windmill blades spin faster (more speed). When we blow more, we are giving the windmill blades more energy and working harder to make them spin faster.*	**Observations** *When we kick the ball hard, it goes faster (more speed). When we kick it softly, it rolls pretty slowly (less speed). When we kick the ball hard, we are giving it more energy because we are working harder to make it go.*

Draw Initial Conclusions 5 minutes

Ask students to work with their groups to write a response to the Phenomenon Question **What is the relationship between energy and speed?** in their Science Logbooks (Lesson 6 Activity Guide) by using their observations as evidence. Debrief students' initial conclusions as a class.

Sample student responses:

- *When something is given more energy, it moves faster. It took more of my energy to make the soccer ball move faster, but the harder I kicked it, the more energy I put in and the faster the ball moved.*

Teacher Note

Students may not use the term *speed* at this point in the lesson set. Instead, they may describe how fast or slowly something moves. In the next lesson, students study this term in more detail and learn that speed describes the distance an object travels over a specific time (5F).

Spotlight on Knowledge and Skills

The goal of this lesson is for students to describe the relationship between energy and speed. Students may suggest that energy of motion (kinetic energy) is a type of energy, so moving faster indicates more energy of motion. If necessary, facilitate a discussion to explore cause and effect. Note that, based on what students observed in the investigation, putting more energy into a system causes the objects in the system to move faster.

- *Our group found that the more energy we added to try to move an object, the faster the object seemed to move. At the pull back car station, when we put in more energy by pulling the cars back farther, they moved faster.*

Check for Understanding

Review students' responses to the Phenomenon Question to check for understanding of the connection between energy and speed.

Evidence

Look for evidence that all students

- explain that more energy put into a system results in greater speed of the object, and
- cite relevant evidence from observations.

Next Steps

If students do not draw a connection between energy input and speed, repeat the investigations in a small group or one-on-one. Ask students how they can make the objects move quickly or make them move slowly. Point out the relationship between how much energy they give to an object and how quickly it moves.

Land 10 minutes

Begin the Land by working with students to clarify where energy comes from.

▶ Where do you think the energy came from at the stations?

- *At each station, the energy came from us. We pulled the cars back, our breath made wind, and we kicked the soccer ball.*
- *The energy came from us because we used our energy to move the objects at each station.*

▶ If the energy comes from us, where do we get the energy?

- *The energy that we give the objects comes from our muscles.*
- *Our bodies get energy from the food we eat.*

Teacher Note

To avoid a common misconception about conservation of energy, it is important to discuss that the energy possessed by something is neither created nor destroyed (e.g., a windmill does not create energy or destroy it). If needed, expand on this idea by leading a discussion about energy in humans. The question can be asked as a follow-up to student responses or as a new question. To check for understanding that energy is neither created nor destroyed, listen for students to acknowledge that humans do not *make* their own energy; rather, they get energy from sources such as food (3B).

After students share, revisit the class prediction about the relationship between energy and speed.

- ▶ **Were your results what you expected? What evidence did you gather to evaluate our prediction?**
  - *Yes, the evidence we gathered agrees with our prediction because we saw the same result at every station. Giving an object more energy made it move faster.*

Explain that scientists must design fair tests and be very precise in testing a prediction and collecting data as evidence.

- ▶ **Why might the tests you conducted not be fair? Did each group test the objects in the same way?**
  - *Some groups rolled the ball while others kicked it hard. So, maybe it wasn't fair.*
  - *Some groups had the pull back cars travel across the classroom, and others had them travel just across the desk.*

Tell students that in the next lesson they will design a fair test investigation to further test the class prediction and answer the Phenomenon Question with more confidence.

Optional Homework

Challenge students to think about the connections among wind, speed, and windmills by deciding on a good location for a windmill in their area. Students may be aware of areas in their town that are particularly windy, which could be a good location for a windmill. Ask them to make a list of other factors they might need to consider.

Extension

While many factors influence the placement of windmills, students should be able to make a connection between areas with high wind speeds and the location of windmills. Students may also want to research the locations of windmills near them. Challenge them to think about why these locations were chosen.

Lesson 7

Objective: Interpret data showing that greater energy input enables greater speed.

Agenda

Launch (3 minutes)

Learn (38 minutes)

- Design a Fair Test Investigation (13 minutes)
- Conduct the Investigation (15 minutes)
- Analyze and Interpret Data (10 minutes)

Land (4 minutes)

Launch 3 minutes

Begin by reviewing the Phenomenon Question **What is the relationship between energy and speed?** Ask students to recap their current understanding of this question.

Sample student responses:

- *We think that when we give something more energy, it moves more quickly. For example, when we gave the cars more energy by pulling them back more, they went faster and farther. They moved more. Also, when we put more energy into the soccer ball by kicking it harder, it rolled faster and farther.*
- *When we don't give something as much energy, it moves less quickly. When we kicked the ball softly, we were putting less energy into it, and it didn't seem to go as fast or as far.*

Tell students they will design a fair test investigation to test the class prediction they made in the previous lesson.

Sample class prediction:

When we give an object more energy, it will move faster.

Explain that students must use the following materials to design their investigation: a ball bearing, a ruler, and a textbook. To test the class prediction, students must find a way to give different amounts of energy to the ball bearing and then determine which amount of energy causes the ball bearing to move fastest.

Share the investigation question: How can giving an object more energy affect its speed? Ask students to record the question in their Science Logbooks (Lesson 7 Activity Guide).

Learn 38 minutes

Design a Fair Test Investigation 13 minutes

Before students design their investigations, demonstrate a race between two students to clarify how to quantify speed. Stand at one end of the classroom and explain that when you say "go," Student A will run to you quickly (and safely) while Student B will walk to you slowly. Allow the students to demonstrate.

▶ Why did Student A win?

- *Student A ran, and the other student walked. Student A used more energy.*
- *Student A was faster.*

▶ What does ***faster*** mean?

- *It means Student A had more speed.*
- *It means it took Student A less time to get to you.*

▶ What was the same for both students? What was different?

- *The distance they raced was the same.*
- *They both started at the same time when you said "go."*
- *The time it took Student B to reach you was different. It took more time. That means Student B had a slower speed.*

Teacher Note

The phrase *fair test* refers to an investigation that demonstrates consideration of all variables in its design. In this module a fair test means that one must control variables during the investigation, gather data the same way for each trial, and use appropriate measuring tools to obtain accurate data.

Teacher Note

Students may benefit from examples of investigations that do not provide a fair test. Have students think back to the investigation in Lesson 6 and discuss why those trials were not fair tests and how they could be improved. For example, when students kicked the soccer ball, the ball was given more energy or less energy depending on the student kicking it. In a fair test, the ball would need to be given the same amount of energy in each trial.

Tell students that **speed** is the distance an object moves in a certain amount of time. When measuring and comparing speeds, the distance an object moves (across the room during the race) AND the time it takes to travel that distance (how long it took the student to cross the room) must be considered. To quantify an object's speed, students can mark a *start* line and a *finish* line and use a stopwatch to measure how long it takes an object to travel from the start line to the finish line.

English Language Development

Understanding the term *speed* is essential to this module. Introduce the word explicitly, using the process outlined in the English Language Development section of the Implementation Guide. Discuss meanings of *speed* in different contexts, such as a jet moving at a faster speed than a car. Note that there are no word parts or Spanish cognates available to help students understand its meanings.

English learners may also benefit from explicit introduction of other words in this lesson, such as *data*, *distance* (the Spanish cognate is *distancia*), and *time*.

Divide students into small groups to begin exploring the materials. Remind students that their goal is to plan an investigation in which they vary the different amounts of energy (variable) given to a ball bearing and compare the ball bearing's speeds. Give each group a ruler, a 1" ball bearing, a meter stick, and a 1" or thicker textbook. As students work in small groups to explore and brainstorm investigation plans, ask them to explain why their test will be fair and how they can guarantee reliable results with precise measurements. Ask students to record this information in their Science Logbooks (Lesson 7 Activity Guide).

As they plan with their group, students should consider that changing even one other variable, such as a slight push from their hand on the ball bearing, will change the outcome and result in an unfair test.

Ask students to review the data table in their Science Logbooks. Point out that an extra column is available for an additional trial if they notice any inconsistencies in their data.

Reconvene the class for students to share ideas.

▶ How can you give different amounts of energy to the ball bearing?

- *We could push the ball bearing softly and then push it hard. But that might not be a fair test because people might use different amounts of energy when they try to push hard or softly.*
- *We could lift the ball bearing up a little and then a lot.*

Content Area Connection: Mathematics

Students are not expected to calculate or study rates. Either the distance an object travels or the time it spends traveling must be constant to make this investigation appropriate for students at this level and allow them to compare speeds. Allow students time to discuss which is better for this investigation.

Differentiation

Consider grouping students homogenously by academic level for this investigation. Homogenous grouping in this setting gives students an opportunity to develop social and leadership skills in addition to conceptual understanding.

Teacher Note

Each group should use a textbook with the same width for consistency in data between groups.

Guide students to make a ramp by leaning the end of the ruler against the textbook. Consider demonstrating how to vary the release point by releasing the ball bearing from different heights on the ruler. Ensure that students understand that lifting the ball higher on the ruler (releasing from a greater height) means more energy input. Demonstrate this concept by placing a classroom object, such as a book, on the floor. Lift the object slightly off the floor, and then lift the object high in the air. Ask students to reflect on which action requires more energy to perform.

▶ **In which position does the object have more energy?**

Allow groups to share their investigation plans. As students share, use a whiteboard or chart paper to develop a class investigation plan. Guide students to determine which variables must be controlled to ensure a fair test. Be sure to include the following key ideas in the class plan:

- All groups must conduct their investigation on a flat surface, such as the floor or a long table.
- All groups must set up their ramps the same way (e.g., same textbook set at the same point under the ruler, books oriented the same way) to ensure that the distance is the same from the start line to the finish line (e.g., 2 m).
- All groups must test the same ball bearing release heights to generate different speeds (e.g., 7 cm, 14 cm, 21 cm, and 28 cm marks).
- All groups must complete the same minimum number of trials.
- All groups must use a stopwatch to measure the time it takes for the bearing to travel from the start line to the finish line.

Teacher Note

Highlight the importance of multiple trials in performing a fair test. Guide students toward the understanding that if they perform the same test several times, they should get similar data. Data that vary significantly may indicate a problem with the investigation plan.

Display the investigation plan so students can refer to it throughout the lesson.

Sample class investigation plan:

1. *Conduct the investigation on a flat surface.*
2. *Choose a textbook that has a width of at least 1 inch. Position the book flat on the surface. Lean the ruler flat-side down on the book to create a ramp. Line up the ruler's 28 cm mark with the edge of the book.*
3. *Place a piece of tape on the work surface so that the edge lines up with the end of the ruler. This edge of the tape will be the start line. Measure 2 m from the start line and place another piece of tape to mark the finish line.*
4. *Release the ball bearing from the ruler's 7 cm mark. Start timing when the ball bearing leaves the ruler, and stop timing when it reaches the finish line. Perform three more trials at the 7 cm mark.*
5. *Repeat the investigation, releasing the ball bearing from the ruler's 14 cm, 21 cm, and 28 cm marks.*

Emphasize the importance of timing and accuracy in collecting data. Explain that students may need to run some practice trials to familiarize themselves with using the stopwatch. Ask students when they should start the stopwatch and when they should stop it. Remind students that the release distance on the ruler will change, but the ball bearing will leave the ramp at the same place in each trial. Ensure that the class agrees to start the stopwatch when the ball bearing reaches the bottom of the ramp (i.e., the start line) and stop the stopwatch when the ball bearing crosses the finish line.

Ask students to complete the Release Point on Ramp and Distance Ball Bearing Travels columns of the data table in their Science Logbooks.

Conduct the Investigation 15 minutes

Once students have set up the investigation and are comfortable and confident using the stopwatch, they may begin collecting and recording data in their Science Logbooks.

Encourage students to divide responsibilities among members of the group. Suggested group roles are shown below.

- Ball Bearing Keeper: places the ball bearing on the correct starting point on the ruler
- Timer: times the trial with the stopwatch
- Observer: observes the investigation to ensure a fair test; for example, ensures that the ramp is correctly placed and no factors affect the accuracy of the data collection (e.g., distractions, talking)
- Data Recorder: records data from each trial in the Science Logbook

Analyze and Interpret Data 10 minutes

After conducting all trials, groups complete the Typical Time Value column on their data table. Explain that students should use this column to record the typical time values they observe. Discuss what a typical time value means in this situation. Although *typical value* has a specific meaning in statistics, in this case, students should record the time value that they think best represents the data set.

Sample data table:

Release Point on Ramp (centimeters from bottom)	Distance Ball Bearing Travels (meters)	Time for Bearing to Reach Finish Line (seconds)					
		Trial 1	Trial 2	Trial 3	Trial 4		Typical Time Value
7	*2*	*7.5*	*6.5*	*6.6*	*6.7*		*6.6*
14	*2*	*4.3*	*4.2*	*4.0*	*4.2*		*4.2*
21	*2*	*3.5*	*3.6*	*3.5*	*3.5*		*3.5*
28	*2*	*3.1*	*2.9*	*2.9*	*3.0*		*3.0*

Have student groups begin analyzing the data by working through the Reflection Questions section in their Science Logbooks (Lesson 7 Activity Guide). While groups discuss and record their responses to these questions, visit each group to guide reflection as necessary.

Content Area Connection: Mathematics

Students may be unfamiliar with decimals. Briefly explain the first decimal place (tenths of a second) is related to the fraction *tenths*. To ensure accurate data collection, instruct students to round their data to the nearest tenth, using the digit in the hundredths column to determine whether they should round up or down.

Content Area Connection: Mathematics

For students who struggle to determine a typical time value, provide supports to help them analyze their data. Help students look at the three trials at each release point and pick a time value that best represents their data. If their data points are between 5.3 cm and 5.8 cm, encourage them to pick a number around the midway point. Avoid teaching students to average the measurements.

Teacher Note

During this discussion, students may need to revisit their data tables to understand that a shorter time indicates a higher speed. If necessary, revisit the classroom race example, where running at a higher speed meant finishing the race in shorter (faster) time (3B).

Then ask groups to share their patterns with the class, and discuss the question below.

▶ Can we use our set of data as evidence to support our prediction? Why?

- *Our set of data is accurate because we did four trials and the times were almost the same each time, so we know our measurements weren't a mistake.*
- *All the groups followed the same plan and got similar data. This means our investigation plan is good and we can use the evidence to support our prediction.*

Students write a response to the Final Reflection question in their Science Logbooks.

Sample responses to Reflection Questions in Lesson 7 Activity Guide:

What patterns do you notice in your data?

- *The ball with the most energy (28 cm mark) took the least time to reach the finish line, and the ball with the least energy (7 cm mark) took the most time.*
- *The more energy we gave a ball, the faster it moved.*

Which trials did not follow the pattern(s), if any? What could have caused differences in the data?

- *In Trial 1 for the 7 cm ball, the time was 7.5 seconds, and the other times were 6.5, 6.6, and 6.7 seconds. We may have pressed the button on the stopwatch too late.*

Sample response to Final Reflection question in Lesson 7 Activity Guide:

Revisit the class prediction from Lesson 6. How did today's investigation support or challenge your thinking?

- *We predicted that giving an object more energy would cause it to move faster. When we gave a ball bearing the most energy by lifting it highest on the ruler, it rolled fastest. When we gave a ball the least energy by lifting it to the lowest mark, it rolled slowest. So our evidence supported our prediction.*

Content Area Connection: English

In science, data must meet specific standards to be used as evidence. For example, results should be replicable by other scientists under the same test conditions.

In English, students also evaluate evidence.

Help students draw connections between their experiences evaluating evidence across disciplines.

English Language Development

As they respond to this question, some English learners may benefit from sentence frames like the following (3B).

- Our prediction was _______. This investigation (does/does not) support our prediction because _______.

Check for Understanding

As students reflect on the class prediction, they should demonstrate a growing understanding of the connection between energy and speed.

Evidence

Look for evidence that all students understand that when the ball is released from a higher point on the ruler, the ball has more energy and it moves with greater speed.

Next Steps

Informally note any students who struggle with this concept. While it is not necessary to correct misconceptions at this point, it is important to note which students may need extra support during the next investigation.

Land 4 minutes

Engage students in the next steps by acting out another race scenario with two students. Student A runs quickly across the room, and Student B walks slowly. Stand at the finish line and have students imagine Student A and Student B both accidentally bump into you.

▶ What would happen if Student A bumped into me?

- *You would probably get knocked down and get hurt.*

▶ What would happen if Student B bumped into me?

- *Nothing would really happen. You might move a little bit, but you wouldn't get hurt.*

▶ Why would I get hurt in the first scenario but not in the second?

- *Student A is moving fast, so you'd get hit with more energy.*

Explain that the relationship between energy and speed could have important implications in a **collision**, which is when two objects hit, and exert a force on, each other.

English Language Development

Introduce the word *collide* explicitly, using the process outlined in the English Language Development section of the Implementation Guide. Explore the Latin root *col-*, which often means "together." Pointing out related words, such as *collision*, may be beneficial. Discuss meanings of *collide* in different contexts, such as a baseball and a bat colliding when the batter swings and hits the ball (3B).

▶ What questions do you have about collisions after imagining Students A and B bumping into me?

- *Would Student A really make you move, or would he just be stopped from moving forward?*
- *Is there always a sound when two objects collide?*
- *Why is it that sometimes after two objects collide, one or both objects move the other way, like when two toy cars crash?*
- *Sometimes a moving object stops after a crash. What happens to that object's energy?*

Tell students that to explore their questions, in the next lesson they will investigate the Phenomenon Question **What happens to energy when objects collide?**

Lessons 8–9

Energy Changes during a Collision

Prepare

In Lessons 6 and 7, students concluded that transferring more energy to an object allows it to move with more speed. In Lesson 8, students build on the investigation from Lesson 7 by investigating how far objects moving at various speeds can move a second object after a collision. Students then graph their data to identify patterns in the transfer of energy between colliding objects in the ball bearing and catch system. In Lesson 9, students make sense of their investigations by developing a model to explain what happens to energy during a collision. Because energy transfer and transformations occur before, during, and after a collision, students model each stage to track the presence of energy phenomena.

Concept 2: Energy Transfer

Focus Question

How does energy transfer from place to place?

Phenomenon Question

What happens to energy when objects collide?

Student Learning

Knowledge Statement

Energy in a system can transfer between objects through collisions, causing changes in their motion.

Objectives

- Lesson 8: Predict the transfer of energy of motion between objects during a collision.
- Lesson 9: Explain the transfer of energy of motion between objects through forces in a collision.

Texas Essential Knowledge and Skills Addressed

4.2A **Plan** and implement descriptive **investigations**, including **asking** well defined **questions, making inferences**, and selecting and **using appropriate equipment** or technology **to answer** his/her **questions**. (Addressed)

4.2C **Construct** simple tables, **charts, bar graphs,** and maps using tools and current technology **to organize, examine, and evaluate data**. (Addressed)

4.2D **Analyze data and interpret patterns to construct reasonable explanations from data that can be observed and measured.** (Addressed)

4.2F **Communicate** valid **oral and written results** supported by data. (Addressed)

4.3B **Represent the** natural **world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)

4.4 **Collect, record, and analyze information using tools,** including calculators, microscopes, cameras, computers, hand lenses, **metric rulers,** Celsius thermometers, mirrors, spring scales, balances, graduated cylinders, beakers, hot plates, meter sticks, magnets, collecting nets, and **notebooks**; timing devices; and materials to support observation of habitats of organisms such as terrariums and aquariums. (Addressed)

4.6D **Design a descriptive investigation to explore the effect of force on an object** such as a push or pull, gravity, friction, or magnetism. (Introduced)

English Language Proficiency Standards Addressed

2C Learn new language structures, expressions, and basic and academic vocabulary heard during classroom instruction and interactions.

4A Learn relationships between sounds and letters of the English language and decode (sound out) words using a combination of skills such as recognizing sound-letter relationships and identifying cognates, affixes, roots, and base words.

5G Narrate, describe, and explain with increasing specificity and detail to fulfill content area writing needs as more English is acquired.

Materials

		Lesson 8	Lesson 9
Student	Science Logbook (Lesson 8 Activity Guide)	●	
	Collision Investigation (per group): textbook (at least 1″ thick; the same type or size for each group), 2 rulers, 1″ ball bearing, tape, ball bearing catch	●	
	Science Logbook (Lesson 9 Activity Guides A and B)		●
Teacher	Anchor chart, anchor model		●
Preparation	None		

Lesson 8

Objective: Predict the transfer of energy of motion between objects during a collision.

Launch 3 minutes

Teacher Note

In Lessons 8 and 9, students build a foundation to understand how energy changes forms. Help students understand how energy transfers to other objects by giving examples, such as energy transfer from electrical wires to a speaker. Transfer of energy will be further developed in later grades.

▶ Can you name some things that collide?

- *A foot and a soccer ball*
- *Cars, if they get into an accident*
- *Football players*

Remind students of the collision discussion at the end of Lesson 7, and allow them to ask any additional questions they have about collisions. Add these questions to the driving question board.
Ask students to review the Phenomenon Question **What happens to energy when objects collide?**

Explain that investigating collisions will help students develop a better understanding of what happens to energy when two objects collide.

Tell students they will design an investigation in which a ball bearing collides with another object. The second object is called a catch. Their goal is to find out whether a faster-moving ball bearing has more energy than a slower-moving ball bearing and what happens to that energy during a collision. They will compare how much energy the ball bearings have by observing how far the ball bearings push the catch.

Agenda

Launch (3 minutes)

Learn (38 minutes)

- Plan the Investigation (7 minutes)
- Conduct the Investigation (13 minutes)
- Analyze and Interpret Data (18 minutes)

Land (4 minutes)

English Language Development

Students were introduced to the word *collide* at the end of Lesson 7. It may be beneficial to revisit this term as students begin to use it in this lesson.

Share the investigation question: Does an object's speed affect energy during a collision? Students record this question at the top of the Lesson 8 Activity Guide.

▶ How could we vary the ball bearing's speed?

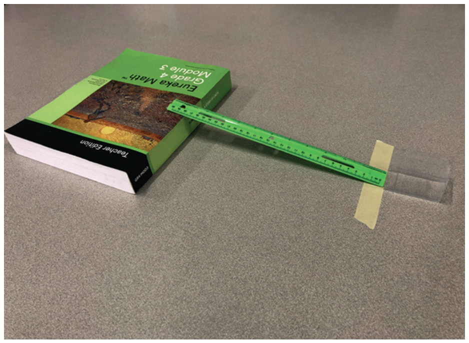
- *We could throw the ball into the catch. But that might not be a fair test since you might throw it harder than me.*
- *We could put more energy into the ball bearing by lifting it higher on the ruler ramp. Our last investigation showed that will make different speeds, so it's a fair test.*

Confirm that students can set up a fair test by varying the release points of the ball bearing again to change its speed and build on the results from the last lesson.

Learn 38 minutes

Plan the Investigation 7 minutes

Perform a quick demonstration to show students how the catch works. In other words, roll the ball bearing down the ramp directly into the catch. Then, demonstrate measuring the distance the catch travels when the ball bearing collides with it. The higher the ball bearing is placed on the ramp, the farther the catch will travel.



Establish an updated investigation plan with students. Emphasize the importance of measuring distance traveled by using consistent reference points, such as the front of the catch. Record the investigation plan, and display it so students can refer to it throughout the lesson.

Teacher Note

Have the investigation materials out and visible to students as they consider this question. Doing so may help remind them of their last investigation, in which they learned to vary the speed of the ball bearing by placing it at different points on the ruler ramp.

Differentiation

During the investigation, the catch only moves a short distance. To make sure all students are prepared to measure this distance, review or remediate measurement concepts. Have students practice measuring and choosing appropriate units of measurement before the investigation.

Sample class investigation plan:

1. *Conduct the investigation on a flat surface.*
2. *Choose a textbook that has a width of at least 1 inch. Position the book flat on the surface. Lean the ruler flat-side down on the book to create a ramp. Line up the ruler's 28 cm mark with the edge of the book.*
3. *Place a piece of tape on the work surface so that the edge lines up with the end of the ruler. This edge of the tape will be the start line.*
4. *Place the ball bearing catch against the end of the ruler so that the front (open side) of the catch lines up with the start line.*
5. *Release the ball bearing from the ruler's 7 cm mark, and then measure how far the front of the catch slides from the start line. Reset the catch and perform three more trials at the 7 cm mark.*
6. *Repeat the investigation, releasing the ball bearing from the ruler's 14 cm, 21 cm, and 28 cm marks.*

Ask students to use this investigation plan to fill in the blank headings in the data table in their Science Logbooks (Lesson 8 Activity Guide). As they prepare the data table, work with students to determine that the best unit of measurement to use is centimeters (cm).

Sample data table:

Release Point on Ramp (centimeters from bottom)	*Distance* **Ball Bearing Catch Travels (***centimeters***)**					
	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*		*Typical Distance Value*
7						
14						
21						
28						

Conduct the Investigation 13 minutes

As students work with their teams to carry out the investigation, move from team to team to ensure that groups are adhering to the investigation plan. Students may need to perform an additional trial if they notice any inconsistencies in their data.

Analyze and Interpret Data 18 minutes

After students complete their investigation, ask teams to identify a typical distance value, or the value that best represents the data set, for each release point on the ruler.

Sample data table:

Release Point on Ramp (centimeters from bottom)	*Distance* **Ball Bearing Catch Travels (***centimeters***)**					
	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*		*Typical Distance Value*
7	*1.0*	*1.0*	*1.0*	*1.0*		*1.0*
14	*2.8*	*3.0*	*3.1*	*3.1*		*3.0*
21	*4.2*	*4.2*	*4.2*	*4.3*		*4.2*
28	*5.3*	*5.5*	*5.8*	*5.3*		*5.5*

Explain that scientists often organize their data for ease of analysis, and one of the ways they do this is by graphing data to reveal patterns. Work with students to determine the appropriate use of the blank bar graph in their Science Logbooks. As they agree on how to create the graph (e.g., agree to graph the typical distance for each release point, agree to use a ruler to mark centimeters as the vertical scale), have them fill in the blank headings and choose an appropriate scale. Assist students as needed as they graph their values.

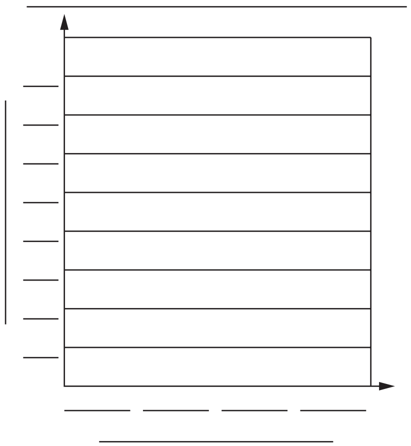
Teacher Note

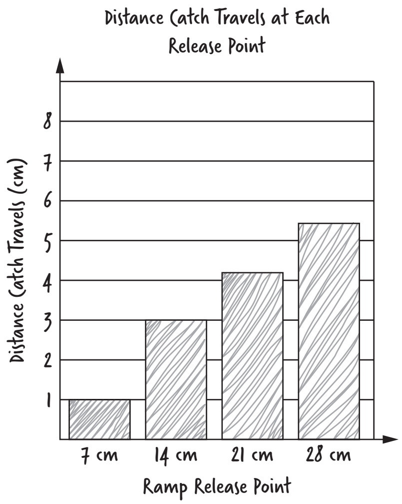
Consider taping a piece of paper to the desk or floor so students can mark the starting and stopping points of the catch for each trial. The catch will then slide on the paper instead of the surface, and students can more easily and accurately measure the distances between the points.

Differentiation

To support students with varying graphing abilities, it may help to record one group's data on the board and then model how to represent these data on the graph. Some students will benefit from working in a small group or one-on-one with teacher support to complete the graph (5G).

Sample blank and complete graphs:





To help students interpret the relationship between the energy of the first object, speed, and the energy of the second object, discuss the following questions.

▶ How do the increasingly higher release points relate to energy? How do they relate to speed?

- *The higher the release point, the more energy we give to the ball bearing.*
- *From the investigation yesterday, we know that putting in more energy causes the ball bearing to move faster.*

When students agree that the higher release points mean more energy input and greater speed than lower release points, have them add the label *More Energy Input, More Speed* → to the bottom of their graphs.

▶ How does the distance the catch travels relate to energy?

- *I think it takes more energy to push the catch farther.*
- *The catch doesn't have any energy before we start the investigation, and then after the collision, it has energy because it moves. The catch that travels the farthest must have the most energy.*

English Language Development

English learners may benefit from having sentence frames such as the following to make sense of the data and the relationship between energy and speed (5G).

- The _______ (higher or lower) the release point height, the _______ (more or less) energy the ball bearing has.
- _______ (More or Less) energy causes the ball bearing to move with _______ (more or less) speed.
- Giving _______ (more or less) energy to the ball bearing causes the catch to move a _______ (longer or shorter) distance.

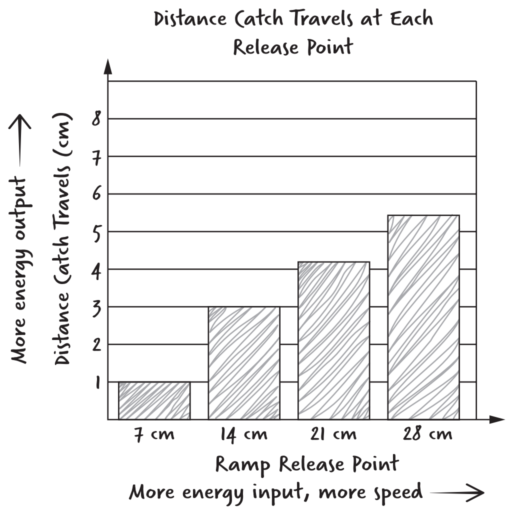
Draw students' attention to the relationship between increased energy and increased force as demonstrated by the catch traveling a greater distance. Ensure that students understand that the ball bearing with the most energy pushes the catch farthest, and the catch with the most energy travels farthest. If needed, ask students to push a classroom object a short distance and a long distance and then reflect on which action requires more energy. Relay that energy entering the system, the energy input, comes from the students. Explain that the catch and ball bearing can be thought of as a **system**, or a group of objects that interact, and the distance traveled is one indicator of energy in that system. Have students add the label *More Energy Output* → along the vertical side of their graphs.

English Language Development

The term *system* is central to this module. Introduce this term explicitly, using the process outlined in the English Language Development section of the Implementation Guide. The Spanish cognate *sistema* may be useful. Discuss the meanings of *system* in different contexts, such as solar system, highway system, and body system.

As with other important words, scaffolds such as oral rehearsal and sentence frames may benefit some English learners throughout the module as they use the term *system* in speaking and writing. English learners may also benefit from explicit introduction of other terms in this lesson set, such as *electric current* (4A).

Sample graph with analysis:



Differentiation

Engage students with a variety of learning styles by using different examples to demonstrate the concept of energy input and output within a system. In the example of a student pushing a classroom object, the energy input came from the student, and the energy output was shown by the distance the classroom object moved.

Teacher Note

To help students better understand the new term *system*, consider using a terminology instructional routine such as a Frayer model (2C).

Land

4 minutes

Remind students that in the last lesson, they explained that greater energy input allows the ball bearing to move faster, but they have not fully explained what happens to that energy after it is given to the ball bearing.

▶ Does the ball bearing have more energy when it moves quickly or slowly? How do you know?

- *I think the ball bearing has more energy when it moves quickly because we gave it more energy by lifting it to the highest point, 28 cm. But I'm not sure if it keeps all the energy we give it.*
- *The fastest ball bearing has the most energy because it moves the catch farthest, and it takes energy to move the catch.*

Check for Understanding

Listen to students' explanations of which ball bearing has the most energy.

Evidence

Look for evidence that students

- identify that the fastest-moving ball bearing (the one released from the highest point) has the most energy, and
- cite the ball bearing's ability to move the catch as evidence of its energy.

Next Steps

If students do not make the connection between energy and the ability to move the catch, discuss how energy makes things happen. Have students push objects such as chairs across the floor, and ask them to imagine they are the ball bearing pushing the catch. Reflect on whether it takes more effort (energy) to move the object a short or long distance.

Confirm that the fastest-moving ball bearing possesses the most energy. Point out that the cause and effect relationship between speed and energy works both ways: (1) the more energy given to an object (e.g., lifting the ball bearing), the greater the speed of that object (e.g., ball bearing rolling); and (2) the greater the speed of the object (e.g., ball bearing rolling), the more energy of motion that object has available to transfer, or move, to other parts of the system (e.g., catch). The process by which energy moves from one part to other parts of a system is called **energy transfer**.

Teacher Note

In previous lessons, students likely used words such as *give* to describe the transfer of energy. From this point forward, encourage students to use the precise terminology, *energy transfer*.

English Language Development

Using the process outlined in the English Language Development section of the Implementation Guide, introduce the word *transfer* explicitly. Break *transfer*, which can be a noun or a verb, into the word parts *trans-* (often means "across") and *-fer* (often means "carry") and explore their meanings. Discuss meanings of *transfer* in different contexts, such as a student who moves and transfers to a different school or the transfer from one subway line to another. Sharing the Spanish cognates for the verb *transferir* and the noun *transferencia* may also be helpful (4A).

Tell students that in the next lesson they will clarify their understanding of the Phenomenon Question **What happens to energy when objects collide?**

Optional Homework

Challenge students to look for examples of the relationship between energy and speed outside of the classroom. Have them explain the relationship to a family member by using a system in their home as an example. Remind students that it often helps to use a model or a graph to explain relationships.

Lesson 9

Objective: Explain the transfer of energy of motion between objects through forces in a collision.

Launch 5 minutes

Ask students to compare the investigations from Lessons 7 and 8.

▶ What differences did you notice between the two investigations and their results?

- *In the second investigation, the ball bearing collided with the catch. In the first, the ball bearing didn't bump into anything.*
- *In the first investigation, the ball bearing kept rolling for a while. In the second investigation, the ball bearing moved with the catch for a second and then stopped.*
- *In the first investigation, the ball bearing just rolled and there was hardly any sound. In the second investigation, the ball bearing hit the container and made a louder sound.*

▶ Why do you think the ball bearing in the catch did not travel as far as the ball bearing by itself?

- *The container was heavy and stopped the ball from rolling.*
- *The catch is flat on the bottom and doesn't roll, so it stopped the ball bearing.*

Point out that students explored two situations in which the same amounts of energy were transferred to the ball bearing, but the ball bearing moved different distances. Because energy does not disappear, there must be an explanation for why the ball bearing moved a shorter distance when it collided with the catch. In this lesson, students will develop an explanation as they continue exploring the Phenomenon Question **What happens to energy when objects collide?**

Agenda

Launch (5 minutes)

Learn (30 minutes)

- Model Energy before a Collision (10 minutes)
- Model Energy during a Collision (10 minutes)
- Model Energy after a Collision (10 minutes)

Land (10 minutes)

- Conceptual Checkpoint (5 minutes)

Differentiation

Use investigation materials from the previous lesson as a visual support for students as they share their responses to these questions.

Tell students that modeling the second investigation may help develop an explanation. Explain that students will model each stage of the collision to track the energy efficiently:

- Before the collision (when students place the ball bearing on the ramp)
- During the collision (when the ball bearing collides with the catch)
- After the collision (when the catch slides to a stop)

Remind students that during their investigation, they tested four different release point heights, which produced four different ball bearing speeds. Ask them to discuss which collision would be the most helpful to model. As students share and challenge one another's thinking, prompt discussion with the following questions as necessary: What is the purpose of our models? Which collision would have the most obvious changes in energy for us to model?

When students agree on which speed to model, have them record it in their Science Logbooks (Lesson 9 Activity Guide A).

Learn 30 minutes

Model Energy before a Collision 10 minutes

Ask students to work with a partner to develop a model in their Science Logbooks explaining what happened before the collision. Before students begin, ask them to reiterate the purpose of this model: to find out what happens to energy when objects collide. Explain the importance of showing where energy is present in their models so that they can accurately track energy at each stage.

Allow students up to 5 minutes to work with their partners to develop their initial models and label where energy is present. When students complete their models, reconvene and develop a class model. Record the model on chart paper or a whiteboard. Students should note that the energy comes from placing the ball bearing on the ramp. If necessary, guide students by asking one or more of the following questions: How did the ball bearing get energy? Where did that energy come from? What did the energy allow it to do?

Teacher Note

Although it may be most revealing to model the collision of the bearing with the fastest speed, modeling any of the four test groups will reveal the same principles.

Differentiation

Some students may need access to the materials from the investigation to help them think through their models. To provide this support, separate students into the same groups from the collision investigation in Lesson 8, and provide each group with the investigation materials (textbook, rulers, ball bearing, tape, ball bearing catch). If providing these supports, allocate additional time for the Learn portion of the lesson.

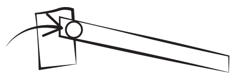
Teacher Note

It may be necessary to explain how to approach these models in the Science Logbook. Space is provided to model energy before, during, and after the collision. Ask students to reflect on which components of the system should be included in each section of the model.

Differentiation

Consider providing unlabeled collision models for students who need additional support. Ask students to label and provide an explanation for each drawing. This will allow these students to focus on developing understanding rather than on drawing (5G).

Sample class model:

Before the Collision  We transferred energy to the ball by placing it high on the ramp.		

Check for Understanding

In Lessons 6 and 7, students focused on the relationship between energy and speed, including how energy entered a system. Use this discussion to ensure that students can apply those concepts.

Evidence

As students discuss their models, listen for the following claims:

- The higher the starting point, the more energy the ball bearing had.
- The energy came from me lifting the ball bearing up to the ramp.
- The energy transferred to the ball bearing caused it to roll with more speed.

Next Steps

If students need to develop these ideas, have them repeat the investigation from Lesson 7 with simple adjustments: double the height of the ramp and then release the ball bearing from only the highest and lowest release points (28 cm and 7 cm). These adjustments will yield more visible differences in speed.

Model Energy during a Collision 10 minutes

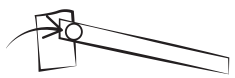
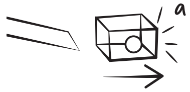
Repeat the process from the previous section by asking students to work with a partner to develop a model in their Science Logbooks explaining what happened during the collision. Before students begin, again ask them to reiterate the purpose of this model: to find out what happens to energy when objects collide. Explain the importance of modeling the moment of the collision between the ball bearing and the catch to find out what happened to energy.

Allow students up to 5 minutes to work with their partners to develop their model. When students complete their models, reconvene and develop a class model. Students should note that during the collision, there was a sound, and the force applied to the catch by the ball bearing caused the catch to move. To guide students to this idea, ask questions such as these:

- ▶ What caused the catch to move?
  - *When the ball bearing hit the catch, a force was applied and it pushed the catch.*
  - *The force applied by the ball bearing transferred some energy to the catch, which made it move.*
- ▶ How did the catch get energy to move?
  - *The motion energy of the ball bearing transferred to the catch when they collided. That's why the catch moved.*

Ensure that students understand that during a collision, the contact forces (i.e., the forces that result when two objects physically touch) cause the transfer of energy to change each object's motion. Students should also note in their initial models that there was a sound as the ball bearing was rolling down the ruler and during the collision. Note this on the class model as a reference for when students model what happened after the collision.

Sample class model:

Before the Collision	During the Collision	
 We transferred energy to the ball by placing it high on the ramp.	We noticed a sound.  The force from the collision pushed the catch, transferring energy from the ball bearing to the catch.	

Teacher Note

To help students identify the presence of other energy indicators during the collision, it may be necessary to revisit the anchor chart from Lesson 5. To guide students to identify the presence of sound, ask them to consider whether any of the other energy indicators on the anchor chart were present during the collision.

Model Energy after a Collision 10 minutes

To finish modeling the collision, repeat the process from the previous sections by asking students to work with a partner to develop a model in their Science Logbooks explaining what happened after the collision. Explain the importance of modeling where they notice energy after the collision.

Allow students up to 5 minutes to work with their partners to develop their model. When students complete their models, reconvene and develop a class model. Students should note that after the collision, the catch slid across the surface while making a noise and then came to a stop.

Ask students to share their thinking with the following prompts. Allow students to challenge one another's thinking based on the evidence they saw after the collision. Guide students to notice that indicators of energy other than motion are present after the collision.

▸ What happens to the energy from the ball bearing? Why does it stop moving? Where does the energy go?

- *The energy from the ball bearing gets used up moving the catch across the floor.*
- *There was a lot of sound during and after the collision. Sound is an indicator of energy, so maybe some of the energy made sound.*

Ask students to rub their hands together to mimic the catch sliding on the ground. Have students share what they notice: There is a sound, and their hands get warmer, which both indicate the presence of energy.

▸ Why do you think the ball bearing and catch didn't travel as far as the ball bearing by itself, even though you put in the same amount of energy? What differences did you observe between the investigations?

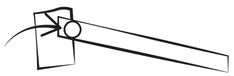
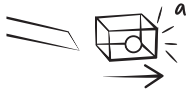
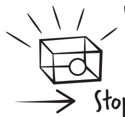
- *The ball bearing had to transfer some energy to move the catch.*
- *Things that are flat on the bottom (like the catch) don't roll because they slide across the ground. Some of the energy might change to sound or cause a temperature change, like when we rub our hands.*
- *There was a sound during the collision and then some more noise when the catch slid on the floor. The ball bearing by itself didn't make that much noise. Maybe some of the energy changed to sound.*

Connect this apparent change in energy to students' questions on the driving question board, and agree to revisit this mystery later in the lesson.

Teacher Note

Students may express misconceptions about energy being used up rather than transferred. Students will further develop their understanding about transfer of energy throughout this module.

Sample class model:

Before the Collision	During the Collision	After the Collision
	We noticed a sound. 	We noticed sound when the catch was sliding.  Stop!
We transferred energy to the ball by placing it high on the ramp.	The force from the collision pushed the catch, transferring energy from the ball bearing to the catch.	The catch slid, then stopped. We noticed there was motion, then a sound and less motion.

Land

10 minutes

As a class, discuss how the ball bearing collision investigation helps answer the Concept 2 Focus Question: **How does energy transfer from place to place?** Add key conceptual understandings to the anchor chart.

Sample anchor chart:

Energy
Energy is why things happen.
Energy is present when we observe something happening (moving objects, light, temperature change, sound) or when something helps make something happen (electricity, batteries).
Energy can transfer between objects through collisions, causing changes in their motion. • Transferring more energy to an object can make it move faster. • Faster-moving objects have more energy to transfer to other objects.

Teacher Note

These diagrams help students understand energy relationships without the use of equations, setting the foundation for deeper understanding in high school.

Before the Collision represents potential energy:
$\text{potential energy} = \text{mass} \cdot \text{gravity} \cdot \text{height}$

During the Collision represents kinetic energy:
$\text{kinetic energy} = \frac{1}{2}(\text{mass})(\text{velocity})^2$

After the Collision represents work:
$\text{work} = \text{force} \cdot \text{distance}.$

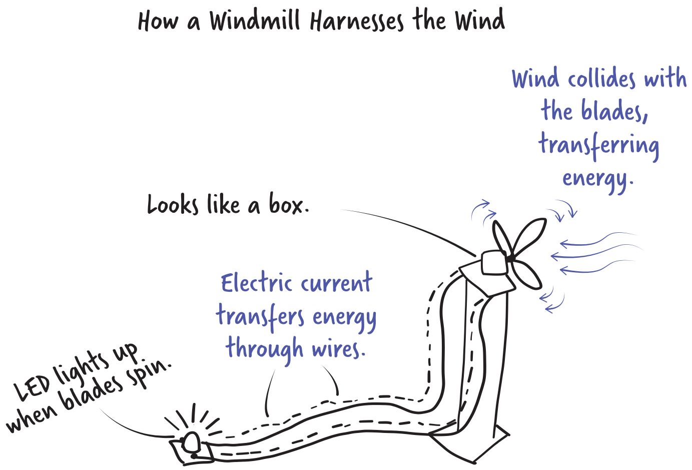
Revisit the anchor model to apply this new knowledge about transfer of energy to the windmill phenomenon. Ask students to identify where energy transfer takes place in the anchor model.

Sample student responses:

- *The wind is pushing the blades of the windmill. This is like when the ball bearing pushes the catch.*
- *The wires connect the blades to the light. So maybe the energy moves through the wires?*

Discuss that energy must move from the windmill to the light through the wires, and electric currents transfer this energy through the wires. Explain that the term *electrical energy* is used to describe this type of energy. Update the anchor chart to include that energy can also transfer from place to place through electric currents in wires.

Sample anchor model:



In the windmill system, wind collides with the blades, which transfers energy to something that looks like a box. An electric current transfers energy through the wires and turns on the light. When the wind blows harder, more energy is transferred to the blades.

Teacher Note

If students begin to discuss why the blades stop turning by sharing ideas about energy transformations, you may add these to the model as well. However, because additional factors cause the blades to stop turning, this depth of understanding goes beyond grade-level expectations.

English Language Development

Allow students to write or draw their ideas about energy transfer in the windmill model on a whiteboard. This can be used as a check for understanding as well as an opportunity for students to gain ideas and clarify misconceptions based on other students' ideas before revising their model (5G).

For more information on using whiteboards as a response technique, refer to the Instructional Routines section of the Implementation Guide.

Teacher Note

Students may use the terms *electricity* and *electrical energy* interchangeably. The term *electricity* in everyday language is often used to describe what makes a light turn on; however, in science, the more precise term is *electrical energy.* Although each form of energy is not explicitly named in this module, teachers may encourage students to use more precise language to discuss energy.

Sample anchor chart addition:

Energy can transfer between objects through collisions, causing changes in their motion.

- Transferring more energy to an object can make it move faster.
- Faster-moving objects have more energy to transfer to other objects.

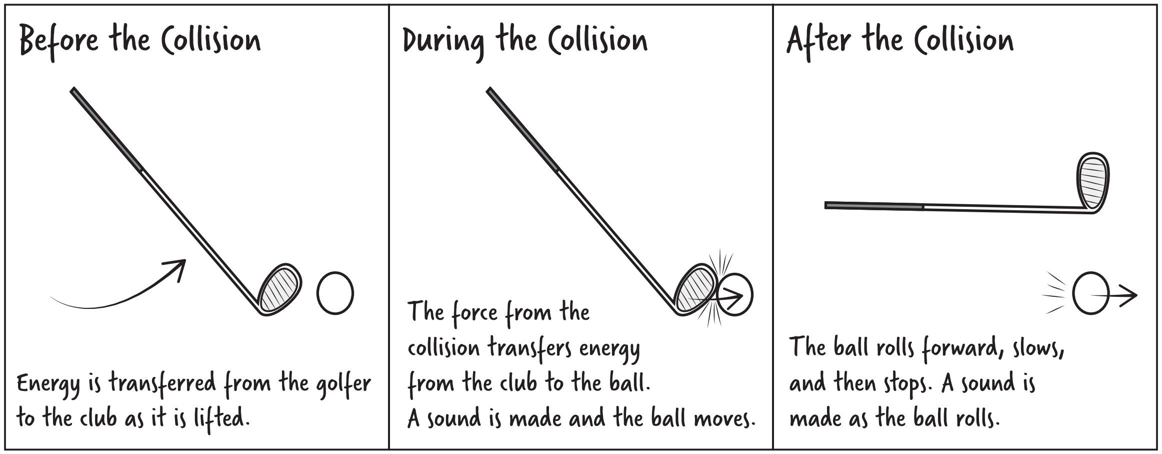
Energy can also transfer from place to place through electric currents.

Conceptual Checkpoint 5 minutes

Tell students they will have an opportunity to demonstrate their learning about energy transfers as they complete the Conceptual Checkpoint in their Science Logbooks (Lesson 9 Activity Guide B). Ask students to imagine they are playing miniature golf and have just hit the ball.

▸ Draw a model and explain each stage of the collision between the golf club and ball by using what you have learned about energy transfers.

Sample student response:



Teacher Note

In the next set of lessons, students learn that there are other ways that energy can be transferred as well—by light, sound, and heat. Leave room on the anchor chart to add these concepts.

Conceptual Checkpoint

This Conceptual Checkpoint assesses the Concept 2 Focus Question **How does energy transfer from place to place?** Students should demonstrate understanding of collisions and energy transfer.

Evidence

Look for evidence that students understand collisions and energy transfer. Student models and responses should reflect the following understanding:

- Energy is transferred from the student to the golf club.
- The force from the collision pushes the object, transferring motion energy.

Next Steps

Work with students in need of support to improve their models and responses. Use the class models that students developed during Lesson 9 to coach students to make improvements.
If necessary, work with students to repeat this Conceptual Checkpoint by using an example from Lesson 6.

Direct students to the list of related phenomena at the bottom of the driving question board. Allow them to Think–Pair–Share about how their new learning can explain these student-generated phenomena. Guide students to make connections between what they know about energy transfers and the phenomena.

Ask students to look back at the driving question board. Add any new questions and ask students to determine the next steps.

▶ Now that we have determined how energy transfers from place to place, what is our next big question?

- *Now we need to find out how motion can become sound.*
- *Now we want to figure out how the windmill changes the energy in wind to the energy in light.*

Use this discussion to connect back to students' observations of sound when modeling what happened to energy during and after the collision. Remind students that in the collision investigation, the energy indicators they observed seemed to transform or change from motion to sound. Tell students that **energy transformation** is what causes the changes in energy indicators. Use this to develop the next lesson's Phenomenon Question **What do we observe when energy transforms?**

English Language Development

Using the process outlined in the English Language Development section of the Implementation Guide, introduce the word *transform* explicitly. Discuss the term in different contexts, such as how new ideas can transform your thinking. The Spanish cognate *transformar* may also be helpful (4A).

Lessons 10–11
Changes in Energy Indicators

Prepare

In Lessons 6–9, students began to explore energy transfer and learned that energy can be transferred between objects and by electric currents. In Lessons 10 and 11, students visit six Energy Transformation Stations. After they visit each station, students develop a model to show how energy transforms. They identify patterns and relationships in their observations to understand that energy transferred by light, sound, and heat may transform to produce new energy phenomena. With this new knowledge, students refine the anchor chart and anchor model to answer questions from the driving question board and select new questions to investigate.

Concept 3: Energy Transformation

Focus Question

How does energy transform?

Phenomenon Question

What do we observe when energy transforms?

Student Learning

Knowledge Statement

Energy transforms by changing from one form to another.

Objectives

- Lesson 10: Observe transformation of energy to produce motion, light, sound, and temperature change.
- Lesson 11: Explain that energy may transform to produce new phenomena, such as motion, light, sound, and temperature change.

Texas Essential Knowledge and Skills Addressed

4.2B **Collect and record data by observing** and measuring, using the metric system, **and using descriptive words and numerals such as labeled drawings,** writing, and concept maps. (Addressed)

4.2D **Analyze data and interpret patterns to construct reasonable explanations** from data **that can be observed** and measured. (Addressed)

4.2F **Communicate** valid oral and written **results** supported by data. (Addressed)

4.4 **Collect, record, and analyze information using tools,** including calculators, microscopes, cameras, computers, hand lenses, metric rulers, Celsius **thermometers**, mirrors, spring scales, balances, graduated cylinders, beakers, hot plates, meter sticks, magnets, collecting nets, and **notebooks**; timing devices; and materials to support observation of habitats of organisms such as terrariums and aquariums. (Addressed)

4.6A **Differentiate among forms of energy, including mechanical, sound, electrical, light, and thermal.** (Addressed)

English Language Proficiency Standards Addressed

3F Ask and give information ranging from using a very limited bank of high-frequency, high-need, concrete vocabulary, including key words and expressions needed for basic communication in academic and social contexts, to using abstract and content-based vocabulary during extended speaking assignments.

4D Use prereading supports such as graphic organizers, illustrations, and pretaught topic-related vocabulary and other prereading activities to enhance comprehension of written text.

Materials

		Lesson 10	Lesson 11
Student	Science Logbook (Lesson 10 Activity Guide)	●	●
Teacher	Energy Transformation Station Setup Instructions (Lesson 10 Resource A)	●	●
	Energy Transformation Station Procedure Sheets (Lesson 10 Resource B)	●	●
	Stations 1a and 1b (2 per class): Snap Circuits® Green kit (solar cell, horn, black jumper wire, red jumper wire), radiometer, black construction paper (if using sunlight as light source) OR flashlight	●	●
	Stations 2a and 2b (2 per class): high-quality balloon (1 per student), 9-ounce clear plastic cup, piece of plastic wrap (large enough to fit over cup), rubber band, 1 tbsp of dry rice, speaker and audio source (if available)	●	●
	Stations 3a and 3b (2 per class): 5 cups of ice, 5 9-ounce clear plastic cups, large bowl, 2 heat lamps, 2 small binder clips, 2 mercury-free classroom thermometers	●	●
	Extension Resources (optional, Lesson 10 Resources C through F)	●	●
	Anchor chart, anchor model, driving question board		●
Preparation	Set up Energy Transformation Stations.	●	●
	Cut out and display Energy Transformation Station Procedure Sheets at each station.	●	●

Teacher Note

Flashlights are listed in the materials table for both light stations (Stations 1a and 1b). However, investigations at these stations can also use sunlight as the light source (either outside or near a sunny window) and a black piece of construction paper to block the sunlight from the devices. Keep in mind that activities involving sunlight have many uncontrollable variables.

Lesson 10

Objective: Observe transformation of energy to produce motion, light, sound, and temperature change.

Agenda

Launch (5 minutes)

Learn (35 minutes)

- Observe and Model Energy Transformations (35 minutes)

Land (5 minutes)

Launch 5 minutes

Teacher Note

In Lessons 10 and 11, students build a foundation to understand how energy changes forms. Help students understand how energy transfers to other objects by giving examples, such as energy transfer from electrical wires to a speaker. Transfer of energy will be further developed in later grades.

Remind students of the Phenomenon Question they developed at the end of the previous lesson: **What do we observe when energy transforms?** Review by discussing the following question:

▶ What indicators of the presence of energy have we observed?

- *We have seen light from the LED, heat lamp, and flashlight.*
- *The pull back cars and the windmill moved.*
- *The heat lamp and rubbing our hands together caused a temperature change.*
- *The radio and the collisions from the pull back cars and ball bearing made sound.*

Explain that students will explore the Phenomenon Question by visiting six Energy Transformation Stations in small groups. The stations will be organized by type of energy transfer: light, sound, and heat. Two of each station should be set up.

Content Area Connection: English

Use the words *transfer* and *transform* to study the Latin prefix *trans*-, which often means "across" or "change." Studying morphology supports giving students clues to understand the meaning of words. Break down transform into *trans*- and -*form*, and discuss how *transform* means to change forms. Consider exploring related words, such as *transferrable*, *transformation*, *transport*, *transcontinental*, *translate*, *transparent*, and *translucent*.

Teacher Note

Students have studied the transfer of energy between objects (collisions) and from place to place by electric currents in previous lessons. While these stations focus on three other types of energy transfer (light, sound, and heat), avoid naming the stations until after debriefing in Lesson 11.

Learn 35 minutes

Observe and Model Energy Transformations 35 minutes

Review class expectations for working in small groups, and then divide the class into groups. Before students begin working at the stations in their groups, ask the class to observe Station 3a (Ice Melt). Students record initial observations of the ice in each cup in their Science Logbooks (Lesson 10 Activity Guide) to compare with their observations later in the lesson.

Safety Note

Several stations in this lesson pose potential hazards. To minimize the risk, review these safety measures and look for evidence that students are following them (4.1A):

- Reiterate the safety measures discussed for the Heat Lamp Station in Lesson 4.
- If using a flashlight in Stations 1a and 1b, do not look directly into the flashlight when it is turned on.
- If using Extension Station 3c, only adults should use the box cutter (or scissors) at the Solar Oven Station. Keep the box cutter in a secure location when not in use.

Student groups work at each set of stations for 10 minutes, following the directions on the provided Procedure Sheet. Circulate to support teamwork and encourage students to record detailed observations in their Science Logbooks. After students finish working at their first station, they switch to the second station. For example, students who finish Station 1a move to Station 1b, and students who finish Station 1b move to Station 1a.

After students finish both stations, give them time to draw a model in their Science Logbooks that explains how energy transforms at one of the two stations. Students should use their knowledge of energy and how it is transferred as well as their new observations at the stations to draw the model.

Next, students rotate to the second set of stations. More details about each station are shown on the following pages. Students complete the third set of stations the next time class meets.

Differentiation

Consider the following factors when grouping students: English proficiency, individual learning supports, team dynamics, and student interest in science.

Teacher Note

Sample student group flow:

1. Two groups work at Stations 1a and 1b and then switch.
2. Groups develop a model and then move together to Stations 2a and 2b.
3. The two groups work at Stations 2a and 2b and then switch.
4. Groups develop a model and then move together to Stations 3a and 3b.
5. The two groups work at Stations 3a and 3b and then switch.
6. Groups develop a model.

Extension

Lesson 10 Resources C through F include directions and an activity guide for additional, optional Energy Transformation Stations. If time allows, use these stations as an extension or to support students who still struggle to understand energy transformations.

Station 1a: Solar Cell

The Solar Cell Procedure Sheet directs students to add and remove a light source near the solar cell. Students record observations about how the horn's output varies when they add and remove light.

Sample student observations:

- *We hear a sound when we shine light on the solar cell.*
- *After we remove the light from the solar cell, the sound stops.*

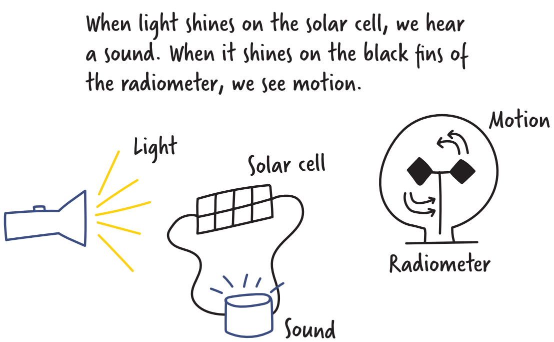
Station 1b: Radiometer

The Radiometer Procedure Sheet directs students to add and remove a light source near the radiometer. Students record observations about how the movement of the radiometer changes as they add or remove light or move the light source to shine on the white or black sides of the radiometer fins.

Sample student observations:

- *The radiometer fins don't move unless light shines on the black side.*
- *When light shines on the white side, nothing happens.*
- *When we remove the light source from the black side, the radiometer stops moving after a while.*

Sample light model:



Teacher Note

As students experiment with the solar cell, encourage them to try pointing it at different angles relative to the light source. They will notice the horn's output is greatest when the solar cell is pointed directly at the light. Make connections to solar energy that students learned about in the Earth Features module. Point out how this relationship affects the placement of solar panels on the roof of a home or other structure. Encourage students to think about which area of the roof at home or at school receives the most direct sunlight.

Differentiation

For students with hearing impairments, use the red LED instead of the horn to make this investigation accessible.

Teacher Note

For time considerations, the activity guide asks students to draw a model to represent what happens at *one* station. Note that the provided sample model combines both stations for reference.

If time allows, consider having students draw a model to represent what happens at both stations to help them make additional connections between the two stations.

Sample model explanations:

- *When light shines on the solar cell, the horn makes a sound. Energy must have transferred through the air, from the horn to our ear. Energy transforms because the indicator of energy changed from light to sound.*
- *When light shines on the black fins of the radiometer, the fins move (they rotate). Light made the radiometer move, so energy transformed from light to motion.*

Station 2a: Balloon

The Balloon Procedure Sheet directs students to blow up a balloon and let the air out. Students record observations about how the sound varies when they release or close the end of the balloon. At this station, students may begin to draw conclusions that air must collide with an object to produce a sound.

Sample student observations:

- *The balloon only makes a sound after we blow it up and let the air out.*
- *There is no sound if air isn't moving through the opening of the balloon.*

Station 2b: Sound Cup

The Sound Cup Procedure Sheet directs students to create a "sound cup" by covering the opening of the cup with plastic wrap and securing it with a rubber band. Students then place a few grains of rice on the plastic wrap. Students place the sound cup near a speaker and observe the movement of the rice as they change the volume. If no speaker is available, students may talk or make noises next to the cup and observe the rice's movement as they change the volume of their voices.

Sample student observations:

- *The rice moves more as the volume of the sound increases.*
- *At low volumes, the rice doesn't seem to move at all.*
- *When we talk, we should be close to the sound cup or the rice doesn't move as much.*
- *If we are close to the sound cup when we talk to it, the rice moves more.*

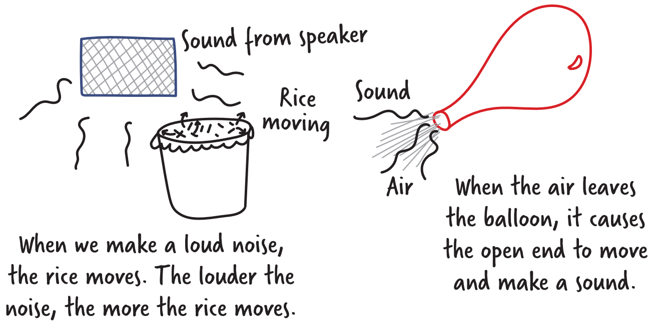
Teacher Note

Teachers can source latex-free balloons to accommodate latex allergies.

Differentiation

Allow students with visual or hearing impairments to touch the cups and feel the vibration.

Sample sound model:



Sample model explanations:

- *Sound is produced as air moves out of the balloon. Energy transfers through the air to bring sound from the balloon to my ear. This means that energy transforms as the air is released. A balloon with more air makes a louder sound when the air is released.*
- *When the speaker is turned on (or when we talk close to the cup), the rice moves. When we turn up the volume (or when we talk louder), the rice moves more. This means that sound transforms into motion.*

Station 3a: Ice Melt

The Ice Melt Procedure Sheet directs students to compare their observations of ice cubes in different ambient temperatures with their initial observations at the start of the class.

Sample student observations:

- *The ice under the heat lamp melts faster than the ice in the cup on the table or in the cup in the bowl.*
- *The ice in the cup in the bowl doesn't melt nearly as fast as the ice in the other two cups.*

Station 3b: Air Temperature

The Air Temperature Procedure Sheet directs students to record the temperature of the air in one cup placed under a heat lamp and in another cup placed away from the heat lamp.

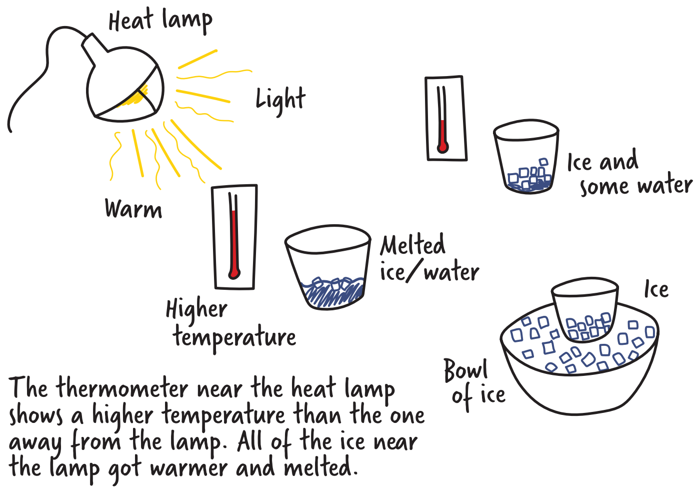
Differentiation

Students with visual impairments can touch the containers to feel which has more ice or water. Consider also providing thermometers that talk or have large-number digital displays.

Sample student observations:

- *The air in the cup under the heat lamp has a higher temperature than the air in the cup away from the heat lamp.*

Sample heat model:



Sample model explanation:

- *Objects under a heat lamp get warmer. The light makes the temperature of the air and the ice increase. It was enough to make some of the ice melt. Energy from the light causes a temperature change.*

Check for Understanding

After completing each type of Energy Station, students record a model to represent the energy transformations they observe. Ensure that students identify and use language to describe energy transformations.

Evidence

Look for evidence that students

- identify changes in the phenomena observed, and
- use language to describe the changes or energy transformations.

Note that some students may include electrical energy or electric current in some of their models, indicating a deeper understanding of the energy transformations they observe at the station.

Next Steps

Consider which students may need additional guidance in the next lesson. These students may benefit from more direct teacher support as they observe, model, and construct explanations of energy transformations.

Land 5 minutes

Tell students they will complete the final two Energy Transformation Stations in the next lesson.

Students Think–Pair–Share to discuss what they have learned so far about the Phenomenon Question **What do we observe when energy transforms?** Students write one statement from their discussions on a sticky note or index card to hand in.

Sample student responses:

- *Somehow energy can produce light and motion. When light shined from the flashlight, the radiometer moved.*
- *Motion can transform into sound. When air moves out of the balloon, it makes a sound. In our collision investigation, we saw motion transform into sound, too.*

Teacher Note

As students begin to use the term *energy transformation* in addition to *energy transfer*, consider using a comparison chart to help students understand the difference between the two terms.

Check for Understanding

As students reflect on what they have learned so far about the Phenomenon Question **What do we observe when energy transforms?** they should have a developing understanding of energy transformation. Energy transformation is a new concept for students. They will continue investigating energy transformation in Lesson 11 and learn that energy can transfer from place to place by light, sound, and heat.

Evidence

As groups share, listen and look for evidence that students

- use the word *transform* while discussing the stations, and
- describe the energy indicators they observed.

Next Steps

Take note of students who may need support in Lesson 11, as they explore the remaining Energy Transformation Stations.

Lesson 11

Objective: Explain that energy may transform to produce new phenomena, such as motion, light, sound, and temperature change.

Agenda

Launch (5 minutes)

Learn (32 minutes)

- Observe and Model Energy Transformations (20 minutes)
- Construct Explanations about Energy Transformations and Energy Transfer (12 minutes)

Land (8 minutes)

Launch 5 minutes

Remind students that they will continue working at the Energy Transformation Stations to explore the lesson's Phenomenon Question: **What do we observe when energy transforms?**

Review the station procedures and safety rules.

Learn 32 minutes

Observe and Model Energy Transformations 20 minutes

Student groups visit the last two stations and record their observations by following the same process they used in Lesson 10. After students complete their investigations for each station, instruct them to develop their third model and write responses to the questions under Constructing an Explanation in their Science Logbooks (Lesson 10 Activity Guide, continued). As students work, circulate to give feedback on their observations, models, and explanations.

Differentiation

Use station materials as visual supports to encourage students to use key vocabulary and specific examples. As students describe energy transformations through the changes observed in the energy indicators, create a class visual or invite students to create their own. By the end of the discussion, a visual might look like this:

- *Light → sound (Solar Cell Station)*
- *Light → motion (Radiometer Station)*
- *Motion → sound (Balloon Station)*
- *Sound → motion (Sound Cup Station)*
- *Light → temperature change (Ice Melt and Air Temperature Stations)*

Check for Understanding

As students complete and update their models with the flow of energy, walk around to listen to their conversations and view their models. Assess their ability to trace the flow of energy observed at each station.

Evidence

Offer feedback on student models and look for the following indications that students may need support:

- Models are missing important components.
- Models are missing key terminology.
- Models do not clearly explain the phenomenon students experienced at the station.
- Models incorrectly identify relationships (e.g., students incorrectly demonstrate the flow of energy in their models).

Next Steps

Ask clarifying questions such as those below, and if necessary, provide specific, actionable feedback to help students develop detailed models.

- Can you talk me through your model? Where is the energy at this point in the system?
- What is your evidence? Where did you observe the evidence at the station?
- Does the system always work that way at the station?

Construct Explanations about Energy Transformations and Energy Transfer 12 minutes

Students use their observations and models to explain what they learned about the answer to the Phenomenon Question **What do we observe when energy transforms?** With students sitting near their group members, discuss the following questions as a class. Throughout the discussion, encourage students to cite evidence from their observations as they explain what they learned.

English Language Development

As in most class discussions, allow students to construct explanations from the Energy Transformation Stations individually or with peers before whole-class sharing. This support may be particularly beneficial to English learners.

You may elect to use the Snowball routine to provide students a low-risk way to share their ideas. After posing the question about patterns in students' observations, invite students to write responses on a piece of paper and then throw the paper across the room. They will then choose one paper at random and share the response with the class.

Spotlight on Knowledge and Skills

In this discussion, students describe evidence of energy transformations and explain that any energy phenomenon may transform into any other energy phenomenon.

Content Area Connection: English

Ensure that student discussions focus on the topic at hand by reviewing key ideas and explaining their own ideas and understanding. Ask questions such as these:

- Who can add to the idea _______ is building?
- What have we concluded so far?

To support students in answering these questions, allow group members more time to discuss the questions. See Speaking and Listening Supports in the Implementation Guide for more resources.

▶ **Which energy indicators helped you observe energy transform?**

- *When the light shines on the solar cell, we think energy transforms because it turns on the horn.*
- *When light shines on the radiometer, we think energy transforms because the fins move.*
- *When the heat lamp is on, the air gets hot. We saw a temperature difference between the thermometer under the heat lamp and the thermometer away from the heat lamp. The ice under the heat lamp also melts faster.*
- *When air moves (motion energy) through the opening of the balloon, we hear a sound. This makes us think that energy is transformed to make sound.*
- *When the sound is louder, the rice has more motion energy. This makes us think that energy moves from the speaker and is transformed into motion energy.*

▶ **What patterns did you notice in those energy transformations?**

- *In all the stations, we saw energy transform from one indicator to another.*
- *It doesn't matter what energy indicator we start with because it can transform in different ways. For example, light can transfer energy and the energy can transform into something like electrical energy and then again into sound.*

Now that students understand where they observed the presence of energy and that it can transform, instruct them to trace the flow of energy in their models for each station. Use follow-up questions such as the following to draw out the conclusion that energy can also transfer from place to place by light, sound, and heat:

- How did the radiometer fins get energy to move?
- Why didn't the fins move when there was no light?
- How did the rice get energy to move?
- How did the ice get energy to melt?

As needed, explain the energy transfer in each station. In Stations 1a and 1b, light transfers energy to the solar cell and the radiometer. In Stations 2a and 2b, sound transfers energy through the air to a student's ear and the sound cup. In Stations 3a and 3b, as the lamp warms the air, energy is transferred as heat from the air to the thermometer and ice, causing the temperature to increase. Summarize that light and sound transfer energy and heat is the transfer of energy from a warmer object to a cooler object (caused by a temperature difference).

English Language Development

As students construct explanations for energy transformations as observed by energy indicators, the following sentence frame may be beneficial (3F):

When we observe _______, we think energy transforms into _______ because _______.

Revisit the driving question board, and tell students they are ready to record new knowledge about the Concept 3 Focus Question, **How does energy transform?**, and expand on their knowledge about the Concept 2 Focus Question: **How does energy transfer from place to place?** On the anchor chart, summarize what students have learned about energy transformations and transfers, referring to their ideas from the discussion.

Sample anchor chart:

Energy
Energy is why things happen.
Energy is present when we observe something happening (moving objects, light, temperature change, sound) or when something helps make something happen (electricity, batteries).
Energy can transfer between objects through collisions, causing changes in their motion. • Transferring more energy to an object can make it move faster. • Faster-moving objects can transfer more energy to other objects. Energy can also transfer from place to place through electric currents, sound, heat, and light.
Energy transformation occurs when we observe one energy indicator changing into any other energy indicator(s).

▶ How does our new knowledge of energy transformation help explain how a windmill turns wind into light?

- *In the windmill, energy transforms from motion (from the air colliding with the blades) into electrical energy (going through the wires) and then into light (turning the light on).*
- *We know energy can transform by noticing different indicators.*

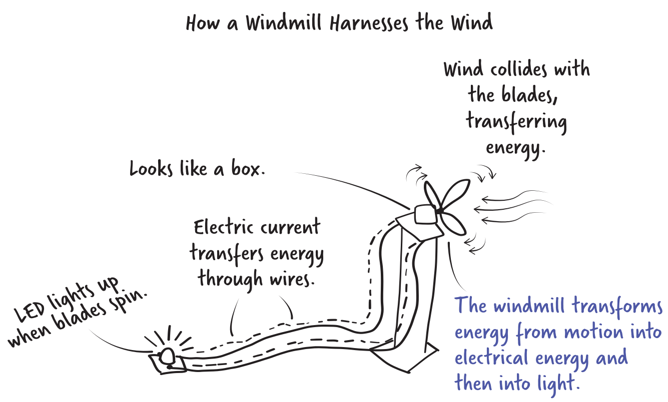
Tell students that the windmill blade's motion energy is a type of mechanical energy. Explain that mechanical energy is the energy that an object has due to its motion or position.

Teacher Note

Mechanical energy of motion is kinetic energy. Mechanical energy of position is potential energy.

Add these new ideas to the class anchor model.

Sample anchor model:



In the windmill system, wind collides with the blades, which transfers energy to something that looks like a box. An electric current transfers energy through the wires and turns on the light. When the wind blows harder, more energy is transferred to the blades. The windmill system transforms energy from mechanical energy to electrical energy and then to light.

Land 8 minutes

Have students independently complete the Summary section of their Science Logbooks (Lesson 10 Activity Guide).

Ask students to consider the related phenomena that they generated earlier in the module. Lead a class discussion about how energy transformation may help explain phenomena on their list.

Revisit the driving question board to determine which questions students have answered and to select questions to drive future investigations.

Teacher Note

Relate the class anchor model of the windmill to what students know about *the story of The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010). How might transforming energy help William achieve his goal to harvest the wind and save his family from starvation?

Teacher Note

Some students may also wish to include the temperature change of the air near the light or the transfer of energy to the air as heat in the anchor model.

Spotlight on Knowledge and Skills

Students think carefully about the scientific explanations they have developed to answer some of their earlier questions. Throughout the discussion, guide students to focus on unanswered questions on the driving question board or in their Module Question Logs that will drive their next investigation of how electrical energy is generated through a transformation of mechanical energy.

▶ What questions on the driving question board can we answer now? Be sure to provide evidence when identifying the questions that we have answered.

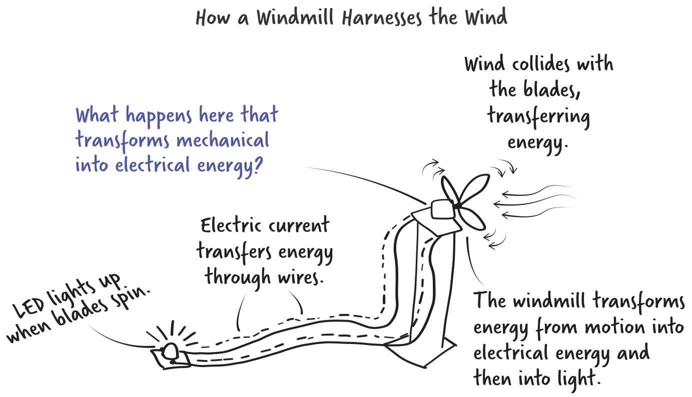
- *How does wind turn into electricity? We now know that mechanical energy can transform into electrical energy.*

▶ What questions on the driving question board do we still wonder about?

- *Where does our electricity come from?*
- *How is electricity made? Does it have something to do with the box behind the windmill?We still don't know what that is.*

Call attention to students' questions about electricity, such as how the windmill generates electricity and transfers it to the LED. Revise the anchor model to reflect this question. Guide students to develop the Phenomenon Question for the next lesson: **How do windmills generate electricity?**

Sample revised anchor model:



In the windmill system, wind collides with the blades, which transfers energy to something that somehow transforms mechanical energy into electricity. An electric current transfers energy through the wires to the light. When the wind blows harder, more energy is transferred to the blades. The windmill system transforms energy from mechanical energy to electrical energy and then to light.

English Language Development

English Learners or striving readers may not be familiar with the term *generate*. Explain that *generate* is another way of saying *produce* or *cause* (4D).

Check for Understanding

Use the Summary activity (Lesson 10 Activity Guide) to gather information about student understanding of one of the Energy Transformation Stations.

Evidence

Look for evidence that all students can develop a detailed model with appropriate supports. Some students may also connect what they learned today to the windmill. For example, "This model helps me understand the windmill because they both take energy from nature and transform it into electrical energy. The energy can then transform into light or sound or something else."

Next Steps

Support students who do not fully understand the concepts in this lesson by encouraging them to revisit previous work as described below.

- Meet with students individually and ask them to explain their models. Take notes on their explanations and ask for more details if necessary.
- After the individual meetings, some students may still need help. They should revisit one of the Energy Transformation Stations, either individually or in a small group. Either way, be present to help students understand what is happening at the station and apply these concepts to the windmill. Consider also revisiting the windmill models.
- After coaching students, ask them to revise their summary model in their Science Logbooks.

Optional Homework

Ask students to use what they have learned about energy so far to explain to a friend or family member how some of the devices in their homes work. Students may wish to draw a model to support their explanation. If time permits in the next lesson, encourage students to share their explanations and models. Display exemplary models in the classroom.

Lessons 12–14
Generating Electricity

Prepare

In previous lessons, students explored energy transfers and transformations. In Lessons 12 through 14, students apply this new knowledge to determine how energy is transferred and transformed in the windmill phenomenon. Student groups build a simple generator and make observations to explain how it plays a role in both energy transfer between the windmill blades and the light and transformation of mechanical energy into electrical energy.

Concept 3: Energy Transformation

Focus Question

How does energy transform?

Phenomenon Question

How do windmills generate electricity?

Student Learning

Knowledge Statement

A generator can be used to transform mechanical energy into electrical energy.

Objectives

- Lesson 12: Plan to build generators to transform mechanical energy into electrical energy.
- Lessons 13–14: Build generators to transform mechanical energy into electrical energy.

Texas Essential Knowledge and Skills Addressed

4.2F **Communicate** valid oral and written **results** supported by data. (Addressed)

4.3B **Represent the natural world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)

4.3C **Connect grade-level appropriate science concepts with the history of science,** science careers, and contributions of scientists. (Addressed)

4.6A **Differentiate among forms of energy, including mechanical,** sound, **electrical,** light, and thermal. (Addressed)

4.6B **Differentiate between conductors** and insulators **of** thermal and **electrical energy**. (Addressed)

4.6C **Demonstrate that electricity travels** in a closed path, creating an electrical circuit. (Addressed)

English Language Proficiency Standards Addressed

3D Speak using grade-level content area vocabulary in context to internalize new English words and build academic language proficiency.

5F Write using a variety of grade-appropriate sentence lengths, patterns, and connecting words to combine phrases, clauses, and sentences in increasingly accurate ways as more English is acquired.

Materials

		Lesson 12	Lesson 13	Lesson 14
Student	Science Logbook (Lesson 12 Activity Guide)	●	●	●
	Science Logbook (Lesson 13 Activity Guide)		●	●
	One-third of a paper towel tube or toilet paper tube (1 per group)		●	●
	Nail (at least 4 inches long; 1 per group)		●	●
	Ruler (1 per group)		●	●
	Copper wire, enamel coated (complete spool of at least 32 m per group)		●	●
	Metallic nuts (2 per group)		●	●
	Magnets (2 sets of 2 magnets per group)		●	●
	LED (1 per group)		●	●
	Sandpaper (1 sheet per group)		●	●
	Alligator clips (2 pairs per group)		●	●
	Science Logbook (Lesson 14 Activity Guide)			●
Teacher	Generator photograph (Lesson 12 Resource)	●		
	Wire cutters (1 per class)		●	
Preparation	Cut paper towel tubes into thirds.		●	

Lesson 12

Objective: Plan to build generators to transform mechanical energy into electrical energy.

Agenda

Launch (5 minutes)

Learn (35 minutes)

- Prepare and Plan to Build a Generator (35 minutes)

Land (5 minutes)

Launch 5 minutes

Remind students of the Phenomenon Question they developed at the end of the previous lesson: **How do windmills generate electricity?** Review how the physical models they built generated enough electrical energy to light an LED.

English Language Development

Introduce the word *generate* explicitly, using the process outlined in the English Language Development section of the Implementation Guide. Discuss the meaning of *generate* in different contexts such as to generate ideas. The Spanish cognate *generar* may be useful. Students will also use the related term *generator* in this lesson.

Students may also benefit from explicit instruction of the term *analyze* (the Spanish cognate is *analizar*) that is also found in this lesson.

▸ Based on our observations of the windmill physical models, how do you think the spinning motion caused by the wind is transformed into electrical energy?

- *There's a box behind the windmill. Maybe that's where the spinning motion gets transformed into electrical energy.*
- *The wires connect the windmill to the light. I think the wires have something to do with transforming energy.*

Teacher Note

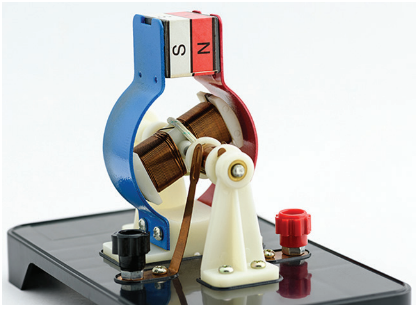
Display a windmill physical model for student reference, and ensure that students can see the generator and wires.

Spotlight on Knowledge and Skills

Ensure students understand that the phrase "generate electricity (or electrical energy)" does not mean that energy is created. "Generate electricity" or "produce energy" typically refers to the transformation of energy into a desired form.

Listen for student responses that mention the device behind the windmill. If needed, prompt with questions such as Which parts of the windmill do we have left to explore? and Which component might play a role in transforming the spinning motion of the windmill blades into electrical energy?

Conclude that students need to explore what happens inside the device behind the windmill to understand how energy of motion is transformed into electrical energy. Explain to students that the component inside the device that transforms mechanical energy into electrical energy is a **generator**. Show students the photograph of a generator (Lesson 12 Resource).



▶ This photograph shows one type of generator. What do you observe in the photograph?

- *It looks like a lot of metal wire is wrapped around something.*
- *I see a magnet at the top of the generator.*
- *It seems like the part covered in wire might spin.*
- *The red and black knobs might be where wires connect.*

Tell students they will build their own generators to transform mechanical energy into electrical energy. This electrical energy will then be transformed into light.

Teacher Note

Science experiments nearly 200 years ago showed that an electric current can be induced in a closed circuit by passing a conductor through a magnetic field or by moving a magnetic field past a conductor.

Content Area Connection: English

Use the word *generate* to explore the Latin and Greek roots *gen-* or *gener-*, which often mean "birth" or "kind." Break down *generate* into *gener-* and *-ate* and discuss how each part relates to the word's meaning. Consider using the Morpheme Matrix routine to explore related words, such as *genetic*, *gender*, *generation*, *genius*, *degenerate*, *regenerate*, and *indigenous*.

Learn 35 minutes

Prepare and Plan to Build a Generator 35 minutes

Remind students that engineers use a specific process when designing, building, and testing a device. They must carefully plan before starting to build. Once the device is built, they test it and then revise it until it works to meet their needs.

▶ **As we build and test our generators, we will follow a similar process. We will start with planning, and then we will analyze what we have constructed and revise it until the generator works effectively.**

As a class, read and discuss the directions for building a generator (Lesson 12 Activity Guide). Review the following safety procedures with the class and instruct students to ask for help if they have questions or are unclear on how to safely use a particular tool or material.

Safety Note

In this lesson, students work with sharp objects (e.g., nails, wires, wire cutters), neodymium magnets, and small metallic nuts. To minimize the risk, review these safety measures and look for evidence that students are following them (4.1A):

- When working with nails, wire cutters, and wire, wear safety glasses or goggles and follow class safety procedures for sharp objects.
- An adult must always help students use wire cutters. Guide students to use this tool appropriately or perform the task for them.
- Students will push a nail through a cardboard tube. Care must be taken to avoid scrapes or punctures. Help students perform this task as needed.
- Because neodymium magnets are very strong, they may be difficult for students to manipulate and pry apart. They are also a pinching hazard. To avoid pinching, show students how to slide the magnets apart. Warn students that if the magnets shatter, they will have sharp edges. Instruct them to ask for help should this occur. It may be useful to prepare the magnets for students' use. This might include setting up the magnet and nail configuration for students before the lesson. Future storage ideas could include keeping the magnet and nail configuration intact to reduce preparation for subsequent classes.

Introduce students to the components of the generator, discuss specific safety concerns, and model best practices. Some of the main components are described below.

- Cardboard tube (a toilet paper tube or one-third of a paper towel tube): This serves as the main structure of the generator. The opening should be wide enough for the magnets to spin inside it.
- Nail: The nail provides a shaft on which the magnets can turn. The nail should go all the way through the tube and must be able to spin. Model carefully keeping hands away from the point of the nail.
- Magnets: The spinning motion of these magnets creates an electric current in the wire, causing electrical energy to flow. If students are curious about how this occurs, explain that it is simply an energy transformation that a generator can perform.
- LED: If students have set up the generator correctly, the LED will glow when the nail is spun. Allow students to make mistakes when connecting the LED to their generators. They will be able to revise their designs later.

Differentiation

For visual learners, consider showing the materials students will use to create their generators as the components are being discussed.

Land 5 minutes

Allow students to ask questions, then revisit the photograph of the generator shown at the beginning of class. Remind students of the Phenomenon Question **How do windmills generate electricity?** Have students identify the parts of the generator that are visible and make predictions about the function of each part in enabling a windmill to generate electricity.

Check for Understanding

Use this opportunity to determine whether students understand the components they will need to create a generator.

Evidence

As students discuss the parts of the generator, listen for evidence of understanding that they will need tightly wound wire, magnets, and a shaft that can spin.

Next Steps

If students do not point out key parts of the generator, revisit the discussion in the Learn section about each component.

Lesson 13

Objective: Build generators to transform mechanical energy into electrical energy.

Agenda

Launch (3 minutes)

Learn (37 minutes)

- Determine Group Roles (7 minutes)
- Build a Generator (30 minutes)

Land (5 minutes)

Launch 3 minutes

Remind students that in this lesson they will start building their generators.

▶ Generators come in different shapes and sizes. Can you think of a time when you may have seen a generator?

- *I've never seen a generator in real life.*
- *My parents have a generator for when the power goes out, but it looks different from the one we saw in the picture.*

▶ Where else do you think you might find a generator that transforms mechanical energy into electrical energy?

- *There's a place near my house with lots of wires and metal boxes. Maybe there's a generator there.*
- *Is there a generator in a solar cell? I remember we turned on a light using a solar cell.*
- *There are generators in the hydroelectric dams we learned about in the last module.*
- *There are generators inside the windmills we built!*

Teacher Note

Students may describe electrical substations or transformer stations. If they do, explain that since electrical wires can be seen both coming into the station and leaving it, the station must be receiving electrical energy that has already been generated (3D).

Teacher Note

If students do not suggest hydroelectric dams, remind them that hydroelectric dams use generators to turn energy from moving water into electrical energy, as they learned in the Earth Features module. In hydroelectric dams, falling water causes a turbine to turn, causing a shaft to turn in the generator, which then produces electrical energy (3D).

Learn 37 minutes

Determine Group Roles 7 minutes

Divide the class into groups of five to eight students and designate work areas. Review class expectations for group work and the class safety procedures.

Suggested group roles are shown below along with the steps associated with each role (see Lesson 12 Activity Guide). Describe the responsibilities of each role and have students follow along with you in their Science Logbooks (Lesson 13 Activity Guide).

- Materials Manager: ensures that the group has the correct materials (Step 1); stores the materials safely at the end of class
- Marker: measures and marks the tube in the correct locations (Step 2)
- Nail Keeper: inserts the nail properly and safely through the tube (Step 3); spins the nail when the generator is ready to be tested (Step 8)
- Magnet Keeper: makes sure the two magnet sets remain separated; places metallic nuts, one on each side of the nail (Step 4)
- Spool Holder*: holds the wire spool loosely so it can spin as wire is wrapped around the tube (Step 5)
- Wire Wrapper: wraps copper wire around the tube; cuts the wire (Step 5)
- Sander*: uses sandpaper to remove the enamel from the ends of the wire (Step 6)
- Connector*: connects the generator to the LED with alligator clips (Step 7)

Once roles are determined and each group has a designated space, distribute materials.

Differentiation

Building a generator is a challenging task, and students will need to pay close attention as they work. Use discretion when forming groups and consider assigning roles based on abilities, interests, and safety concerns.

Teacher Note

Set up materials for each group in a bag or small storage bin. Consider numbering the containers to correspond to each group. At the end of class, students should return their materials to the appropriate bag or bin for use in the next lessons.

*Students in these roles may be given a second role.

Build a Generator 30 minutes

Groups can now begin building their generators.

Circulate to support students as needed and ensure they follow safety guidelines. If a group finishes early, have group members discuss the function of each component they added to their generator and predict the function of components they will add in the next lesson.

By the end of Lesson 13, students should reach the end of Step 4 by marking boundaries for the copper wire, pushing the nail through the tube, and securing the magnets and metallic nuts inside the tube. Students may need extra assistance or supervision while working with the magnets and nuts.

Land 5 minutes

Instruct groups to clean up their workspaces and carefully place their partially built generators and other components in the appropriate numbered bags or bins.

Debrief by having groups share what went well and what was challenging on their first day of construction.

Lesson 14

Objective: Build generators to transform mechanical energy into electrical energy.

Agenda

Launch (5 minutes)

Learn (35 minutes)

- Build, Test, and Modify a Generator (25 minutes)
- Form Conclusions about Generating Electricity (10 minutes)

Land (5 minutes)

Launch 5 minutes

Have students review the next steps for building a generator and their group roles. Use this time to answer any questions they may have about a particular step or instruction.

Remind students that it takes care, patience, and teamwork to create a device that transforms and transfers energy.

Learn 35 minutes

Build, Test, and Modify a Generator 25 minutes

Review class expectations for group work and the class safety procedure for using wire cutters. Students can then retrieve their materials and continue working.

During Lesson 14, students complete their generators by wrapping wire around the tube, cutting the wire, removing the enamel from the wire, and connecting their generator to an LED. Make sure students wrap the wire carefully. If the wire is too tight, it can pinch the tube. If it is too loose, the LED may not light up. Assist or supervise students as needed as they cut the wire.

Sample completed student generator:

When students finish building their generators, they should attempt to light the LEDs and record their observations in their Science Logbooks (Lesson 14 Activity Guide). If the LED does not light up, groups should brainstorm possible design problems with their generator setup. They should then modify the generator and try again. During the revision process, provide guidance to students who have specific questions to help them figure out the problem. Assist with disassembly and revision if needed. The following are examples of possible design problems:

- The opening of the tube has become too small to allow the magnets to spin freely.
- The head of the nail is too close to the tube to grip easily.
- The magnets are not balanced correctly inside the tube.
- The copper wire is too loosely wrapped or is wrapped outside the marked boundaries.
- The enamel has not been completely removed from the ends of the wire.
- The generator is not connected to the LED correctly.

The brightness of the LED will vary depending on how quickly the magnets are spun. If generators are set up correctly but the light is difficult to see, consider dimming the classroom lights. This will also allow students to see more variation in the brightness of the LED.

Once students succeed in lighting the LEDs, instruct them to respond to the questions in their Science Logbooks (Lesson 14 Activity Guide).

Differentiation

Some students may have difficulty capturing their thoughts accurately as they record their observations. These students may benefit from taking a moment to explain their understanding to a partner before recording their thoughts in writing. As students write, coach them to include each of the components they mentioned during their partner discussion (5F).

Teacher Note

Explain that the LED must be connected to the generator in a specific orientation (due to polarity). If the wires are reversed or do not form a complete circuit, the LED will not light up.

Check for Understanding

Use this opportunity to note whether students notice a cause and effect relationship in the generator–LED system and make a connection to what they learned about speed in previous lessons.

Evidence

Listen for evidence that students can relate the speed of the spinning magnets to the amount of energy supplied to the LED (e.g., "When I spun the nail really fast, the light got brighter").

Next Steps

Use responses related to speed to facilitate a class discussion. If students struggle to identify a cause and effect relationship in the generator–LED system, ask students who made this connection to share with the class what they wrote.

Form Conclusions about Generating Electricity 10 minutes

Tell students they will use their observations and analysis to explain their learning about the Phenomenon Question: **How do windmills generate electricity?** Facilitate a student discussion of the questions from the Lesson 14 Activity Guide.

▶ What did you do to cause the LED to light up?

- *We had to spin the nail fast enough.*

▶ What caused the LED to produce different amounts of light? Did you observe a pattern? If so, what was it?

- *If we didn't spin the nail fast enough, the LED didn't light up.*
- *If we spun the nail faster, the LED got brighter.*
- *We discovered during our investigations with the ball bearings that more speed means more energy. So if we spun the nail faster, there was more mechanical energy, which transformed into more electrical energy.*

▶ What energy transfers and transformations did you observe?

- *Energy was transferred from the spinning magnets to the wires and then to the LED.*
- *Mechanical energy was transformed into electrical energy, and that energy was transformed into light.*

Spotlight on Knowledge and Skills

Revisit the relationship between speed and energy. Ensure that students make connections between the speed of the spinning magnets and the amount of energy. For example, the faster the magnets spin, the more energy of motion the magnets possess, and the more electrical energy is transferred, as indicated by LED brightness. Students should also identify the transformation of mechanical energy into electrical energy.

English Language Development

As students analyze and interpret data (Lesson 14 Activity Guide), sentence frames may be beneficial for English learners (5F).

- When we _______, the LED lit up.
- When we _______, the LED did not light up.
- When we _______, the LED got brighter.
- Energy was transferred from _______ to _______ to _______.
- Energy transformed from _______ to _______ to _______.

Teacher Note

Students may think the nail has something to do with generating an electric current. Explain that the nail is simply the shaft that allows the magnets to turn.

Teacher Note

Some students may respond that they first must transfer energy to the nail for it to spin the magnets. This is correct. Expand on these responses by guiding the class to make the connection between the energy they supply to their generators and the energy wind supplies to a windmill's generator.

If needed, review the distinction between energy transfer and transformation. Energy transfer is the movement of energy from place to place, and energy transformation is the change of one energy indicator into another. Allow students to add new ideas to their list of energy transfers and transformations in their Science Logbooks.

Sample student responses:

Energy Transfers	Energy Transformations
▪ *Energy is transferred from the spinning magnets to the wires.* ▪ *Electrical energy is transferred through the wires to the LED.*	▪ *Mechanical energy is transformed into electrical energy.* ▪ *Electrical energy is transformed into light.*

Check for Understanding

Review students' written and verbal responses to gather evidence of student understanding of energy transfers and transformations.

Evidence

Look for evidence that students

- describe what happens to energy by using the words *transfer* and *transformation* appropriately,
- understand that wires transfer energy, and
- understand that energy has many indicators and transforms when one indicator turns into another.

Next Steps

Students missing any transfers or transformations will benefit from individualized feedback on their work. Sample feedback is shown below.

- If students are missing components in energy transfers or transformations, ask them to explain how energy transfers or transforms in a generator and whether they have included all of those examples in their work.
- If students incorrectly identify or reverse energy transfers and transformations, ask them to look back at the energy anchor chart to see whether what they have aligns with what they have discovered so far.

Land 5 minutes

Summarize students' progress in their exploration of the windmill and how it works. Focus on students' new understanding that the device behind the windmill is a generator that transforms the spinning motion caused by the wind into electrical energy. Electrical energy is then transferred along wires to the LED, where it is transformed into light.

Agree to add these details to the class anchor model in the next lesson, when students will revisit the Essential Question: **How do windmills change wind to light?**

Optional Homework

Ask students to develop a list of devices, other than those discussed in class, that they think contain generators. If possible, set aside time during the next lesson to allow students to talk about the devices and explain the evidence they found to support their thinking.

Lessons 15–16
Windmills at Work

Prepare

In Lessons 12–14, students created a generator to better understand how windmills transform the energy of motion into electrical energy. In Lesson 15, students build a key concepts checklist to guide them as they revise the class anchor model. In Lesson 16, students revisit the story of William Kamkwamba. This sets the stage for the engineering challenge introduced in Lesson 17. Students then apply their new understanding of energy to explain how energy is transferred and transformed and answer the Essential Question.

Concept 3: Energy Transformation

Focus Question

How does energy transform?

Phenomenon Question

How do windmills change wind to light? (Essential Question)

Student Learning

Knowledge Statement

Everything that happens can be explained by the transfer and transformation of energy.

Objectives

- Lesson 15: Model how windmills transfer and transform energy.
- Lesson 16: Explain that energy makes things happen when it is transferred and transformed.

Texas Essential Knowledge and Skills Addressed

4.2A **Plan** and implement **descriptive investigations, including asking well defined questions,** making inferences, and selecting and using appropriate equipment or technology to answer his/her questions. (Addressed)

4.2F **Communicate** valid oral and written **results** supported by data. (Addressed)

4.3B **Represent the natural world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)

4.3C **Connect grade-level appropriate science concepts with** the history of science, **science careers, and contributions of scientists**. (Addressed)

4.6A **Differentiate among forms of energy,** including mechanical, sound, electrical, light, and thermal. (Addressed)

English Language Proficiency Standards Addressed

2E Use visual, contextual, and linguistic support to enhance and confirm understanding of increasingly complex and elaborated spoken language.

2F Listen to and derive meaning from a variety of media such as audio tape, video, DVD, and CD ROM to build and reinforce concept and language attainment.

Materials

		Lesson 15	Lesson 16
Student	Science Logbook (Lesson 15 Activity Guide, Lesson 2 Activity Guide)	●	●
	Science Logbook (Lesson 16 Activity Guide)		●
Teacher	Hoover Dam Turbines Photograph (Lesson 15 Resource)	●	
	Anchor model	●	
	Driving question board		●
	The Boy Who Harnessed the Wind by William Kamkwamba and Bryan Mealer (2010)		●
	Key concepts checklist developed in Lesson 15		●
Preparation	None		

Lesson 15

Objective: Model how windmills transfer and transform energy.

Agenda

Launch (5 minutes)

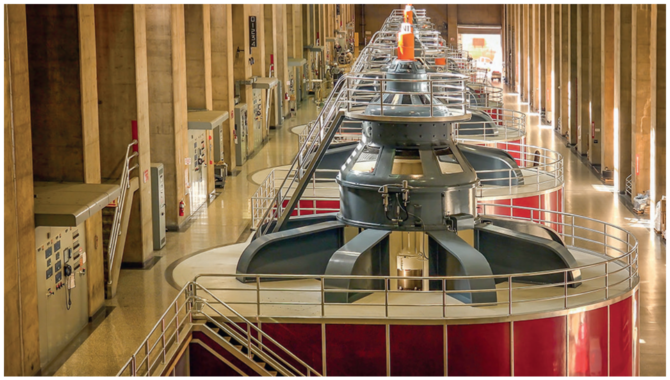
Learn (38 minutes)

- Develop Key Concepts Checklist (10 minutes)
- Revise Initial Models (15 minutes)
- Refine Anchor Model (13 minutes)

Land (2 minutes)

Launch 5 minutes

Remind students that they learned about another use of generators in the Earth Features module by showing them turbines that generate electricity inside the Hoover Dam (Lesson 15 Resource). Ask students to think about what they learned in the previous module about hydroelectric dams.



▶ How do you think the generators in the Hoover Dam compare to the generators you built?

- *Maybe they have a lot of the same parts: wires and something that spins.*
- *They both transform mechanical energy to electrical energy.*

Teacher Note

As necessary, reference the reading *Finding Out about Hydropower* by Matt Doeden (2015, 14–18). A digital version of the text is available on Epic! by opening a free educator account (http://phdsci.link/1036).

- *The dam uses mechanical energy from water, and the windmill uses mechanical energy from the wind.*
- *Our generators are tiny compared to the ones in the Hoover Dam.*

Inform students that, after building a generator in the previous lesson, they are ready to apply their learning to answer the Essential Question: **How do windmills change wind to light?**

▶ How is your generator like the windmill?

- *The magnets spin like the blades of the windmill spinning in the wind.*
- *Both transform mechanical energy into electrical energy, and we know this happens because the light turns on.*

Tell students they will demonstrate their new learning by revising their models of the windmill.

Learn 38 minutes

Develop Key Concepts Checklist 10 minutes

Display the anchor model. Ask students to consider how much they have learned about energy transfers and transformations over the last few weeks. As a class, summarize their learning by developing a key concepts checklist.

▶ What energy concepts should we make sure we show on our model of the windmill?

As students share, listen for key ideas to include on the key concepts checklist. Record the checklist on the board where students can refer to it.

Teacher Note

For background on using key concepts checklists, see these professional resources from Ambitious Science Teaching about a similar technique called "gotta-have" checklists (2E):

- Generalizable Science Ideas: The "Gotta Have" Checklist video (Tools for Ambitious Science Teaching 2013) (http://phdsci.link/1005)
- "Face-to-Face Tools: Making Changes in Student Thinking Visible Over Time" (2015) (http://phdsci.link/1159).

Differentiation

For students who struggle with language, build a word bank from the key concepts checklist that students can use as they move through this lesson. Include *energy*, *transfer*, and *transform* in the word bank.

Sample key concepts checklist:

Key Concepts Checklist
▪ *Energy transformations*
▪ *Energy transfers*
▪ *Relationship between energy and speed*
▪ *Different indicators of energy*

If students overlook key energy concepts, review the anchor chart and discuss which concepts from the chart help explain the windmill phenomenon.

After the class develops the key concepts checklist, students record a copy in their Science Logbooks (Lesson 15 Activity Guide).

Revise Initial Models 15 minutes

Have students revisit the initial model they drew in their Science Logbooks (Lesson 2 Activity Guide). Explain that they will now create an updated model (Lesson 15 Activity Guide). They may include parts from their initial models and add or change elements to represent their new understanding. Remind them to represent the concepts from the key concepts checklist and to show how those concepts apply to the windmill phenomenon.

After creating their revised model, students share their drawing with a partner and discuss the following question: What are the similarities and differences between our models? Students record similarities and differences in the table in their Science Logbooks. Allow students to revise their diagrams based on their discussions. As students work, circulate to observe and support their thinking.

Differentiation

As needed, provide students with individual support. Have visual aids such as physical models from previous lessons or the anchor chart to support students who are struggling to revise their models.

Check for Understanding

Students revise their initial model to reflect new learning about energy.

Evidence

Look for evidence that student models include the following key concepts:

- Energy transformations
- Energy transfers
- Relationship between energy and speed
- Different indicators of energy

Next Steps

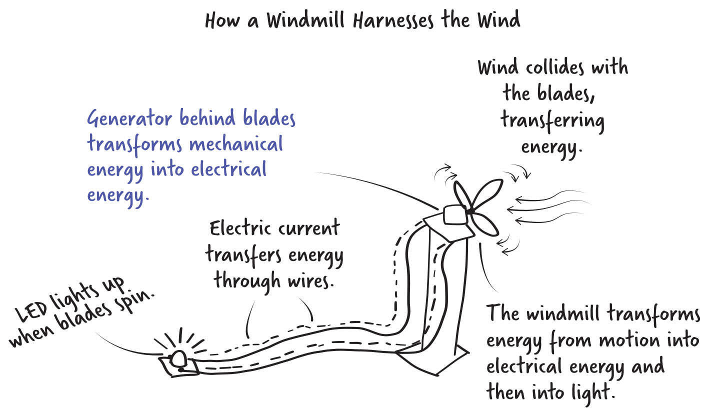
As you circulate, note any students whose models contain key concepts all the models should share. If students do not mention these concepts in the subsequent discussion, call on those students to share their thoughts and their models.

Refine Anchor Model 13 minutes

Invite students to share their revised models with the class by describing new components and labels. As students share new components, encourage other students to use nonverbal signals to show whether they agree that the new component accurately represents how the windmill system works. Call on students to justify their agreement or disagreement with evidence.

If most students agree with the addition of a component and can justify the addition, draw it on the anchor model. Continue asking students what is missing from the anchor model and adding those components until everyone is satisfied that the anchor model successfully explains the windmill phenomenon. As the anchor model develops, students may revise their models as necessary.

Sample anchor model:



In the windmill system, wind collides with the blades, which transfers energy to a generator. The motion of the spinning blades moves the magnets inside the generator, where the mechanical energy of the spinning magnets is transformed into electrical energy. An electric current transfers energy through the wires and turns on the light. When the wind blows harder, more energy is transferred to the blades. The windmill system transforms energy from mechanical energy to electrical energy and then to light.

Review the key concepts checklist, asking students to use nonverbal signals to show whether they think the anchor model represents each concept. Call on students to justify their answers with evidence, and revise the anchor model to represent all key concepts if needed.

Land 2 minutes

Have students explain to a partner their answer to the Essential Question: **How do windmills change wind to light?** Select a few student pairs to share their answers.

Sample student response:

- *When the wind collides with the blades of the windmill, the blades turn, and energy is transferred to the windmill through the force of the air on the blades. The generator transforms the mechanical energy from the blades and the magnets into electrical energy. Electrical energy is transferred through the wires to the light, and the energy is transformed again when the light comes on.*

Tell students that during the next lesson, they will revisit the driving question board to see if they have answered all their questions about energy.

To begin preparation for the engineering challenge in Lessons 17–23, ask students to start bringing in materials from home, such as plastic bottles, plastic or paper plates, straws, paper or polystyrene cups, wooden skewers, and craft sticks.

Lesson 16

Objective: Explain that energy makes things happen when it is transferred and transformed.

Agenda

Launch (2 minutes)

Learn (40 minutes)

- Discuss the Driving Question Board (10 minutes)
- Revisit *The Boy Who Harnessed the Wind* (20 minutes)
- Conceptual Checkpoint (10 minutes)

Land (3 minutes)

Launch 2 minutes

Students have learned a lot about energy throughout the module. Tell students they will update the driving question board with new knowledge and check for unanswered questions.

Explain that students will then discuss how their new knowledge of energy could be used to improve the world.

Learn 31 minutes

Discuss the Driving Question Board 10 minutes

Display the driving question board. Have students discuss which questions they have answered and which questions they still need to answer.

Sample student responses:

- *We have answered almost all our questions.*
- *We still have some questions on the driving question board that we have not answered, but they didn't really fit in as we were figuring out how the windmill worked.*
- *Maybe we can investigate those questions next.*

Coach students to discuss the questions that can now be answered using their new knowledge.

Revisit the list of student-generated phenomena, and allow students time to reflect on how their new knowledge can explain phenomena on the list.

Guide students to continue searching for answers independently to any unrelated questions or phenomena that cannot be explained using what they have learned. If students show significant interest in a particular question, allow them to share what they find with the class in a later lesson.

Revisit *The Boy Who Harnessed the Wind* 20 minutes

▸ How could our knowledge of energy help us make the world better?

- *I could produce light in my basement since it's always dark in there. To get mechanical energy for the generator, I could turn a crank or maybe harness wind from outside.*
- *When I turn off my lights or the TV when I'm not watching it, I'm saving energy since it takes energy to turn them on.*
- *I'm going to be more careful when I ride my bike fast. Since I'm going fast, the bike and I have a lot of energy and could hurt someone in a collision.*

Remind students that another student used his knowledge of energy to solve serious problems in his community. Revisit *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010), and read the book aloud through page 27 this time. After finishing the book, ask student pairs to discuss anything new they noticed and wondered about how William harnessed the wind.

Lead a discussion with text-dependent questions such as those that follow. As needed, reread relevant pages from the book as students discuss the questions, and remind them to cite text evidence to explain their thinking.

Extension

The read-aloud in this lesson does not include the last two pages, which have detailed information about William Kamkwamba. Consider reading and discussing those pages as an extension activity for students.

Content Area Connection: English

Reread *The Boy Who Harnessed the Wind* and discuss how specific words and phrases in the book represent energy (2E).

Content Area Connection: Geography

Use Google Earth™ mapping service to locate William's village of Masitala, Malawi.

Consider providing opportunities for students to research these questions about William and the challenges his community faced. Discuss the geographical characteristics, economy, and culture of Malawi.

English Language Development

As in most class discussions, allow students to consider each question and develop responses individually or with peers before whole-class sharing. Students may benefit from answering the text-dependent questions using a Think–Pair–Share or Jot–Pair–Share. These routines allow individual students to consider their thoughts about each question and then collaboratively discuss the question with peers before sharing with the whole class.

▶ What problems did William hope to solve by building a windmill?

- *People couldn't see at night. They didn't have money for lights. (Page 2)*
- *People were starving. There wasn't enough rain, so their crops weren't growing. (Page 7)*

▶ How could a windmill solve those problems?

- *It could generate electricity for lights. (Page 12) We did that in class!*
- *It could pump water onto the crops. (Pages 11 and 13) The energy must transfer from the windmill to the pump.*

▶ What steps did William take to build his windmill system?

- *He went to the junkyard to find scraps of metal, a tractor fan, and other pieces. (Page 15) He also found a broken bicycle and a generator from a bike headlight. (Page 17)*
- *He asked his friends for help. They chopped trees to make a tower. (Pages 19–20)*
- *He connected wires to a light bulb. (Page 23)*

▶ How do the illustrations on pages 22 and 23 show the types of energy transfer and transformation that make "electric wind"?

- *The blue lines show the wind. I think there is a lot of energy in this wind, because the book says it is a "gusting gale." (Page 21)*
- *The first picture shows that energy is transferred from the wind to the windmill where the blue lines wrap around the blades. (Page 22) On the next page, the wire transfers energy from the windmill to the light bulb. (Page 23)*
- *The second picture shows mechanical energy from the wind transforming into light. (Page 23) The picture only shows the blue lines for wind and yellow for the light, but we know there's probably a generator between the blades and the light bulb that transforms the energy.*

Discuss that although William was just a young boy, he was also an engineer—he worked to solve an important problem that he identified. Use this as an opportunity to explain to students that anyone can be an engineer. Explain that although some engineers develop a new device to solve a problem, others may refine existing technologies to meet new criteria and constraints, which is what William did.

Conceptual Checkpoint 10 minutes

Ask students to recall the Essential Question, **How do windmills change wind to light?**, and then ask them to respond to the following prompt in their Science Logbooks (Lesson 16 Activity Guide). Students may refer to the anchor model, anchor chart, and key concepts checklist as needed.

▶ **A woman in a neighboring village heard about what William did to transform wind energy into electrical energy. She is excited at the idea of using electricity to pump water. Develop an explanation for how this woman can use a windmill to turn on a water pump and provide enough water for her family. Apply all the knowledge from the key concepts checklist.**

Sample student response:

- *The woman can use a windmill to turn on a water pump. First, mechanical energy transfers from the wind to the windmill, making the blades move. Then the generator transforms mechanical energy into electrical energy by producing an electric current. Next, the current transfers energy through the wires that connect the generator to the pump. That is how wind turns into electricity. When the blades spin faster, they have more energy of motion. This means there is more electrical energy being transferred to the pump, which would pump water faster. I know this because in the windmill model, the light is brighter when there is more wind.*

Teacher Note

Students may want to know more about William and his life in Malawi. Share and discuss videos about William, such as *Moving Windmills: The William Kamkwamba Story* (Kamkwamba 2008) (http://phdsci.link/1160) and *How I Harnessed the Wind* (Kamkwamba 2009) (http://phdsci.link/1004) (2F).

Extension

Many engineers and technicians play a role in designing wind turbines (e.g., electrical engineers, mechanical engineers, aerospace engineers, materials engineers). If students are interested, have them research different types of engineers and what they do. Consider asking engineers in the community to come to class and tell the students about their work.

Content Area Connection: English

As students respond to the Conceptual Checkpoint, they can apply relevant writing strategies. For example, students should use precise language to explain their thoughts and use linking words to connect ideas.

Conceptual Checkpoint

Review responses to assess students' ability to apply what they have learned about energy in a new context.

Evidence

Look for evidence that all students can apply the following key concepts in their responses.

- Energy transformation: Energy is transformed from mechanical energy into electrical energy by a generator.
- Energy transfer: Air transfers energy to the windmill, causing the blades to move. The energy is then transferred by an electrical current through the wires to a water pump.
- Relationship between energy and speed: A stronger wind causes the windmill blades to spin faster (more energy of motion); faster-spinning blades cause the water pump to produce more water.
- Different indicators help identify the presence of energy.

Next Steps

Support students who are missing any key concepts or have mistakenly described transfers and transformations of energy. Meet with those students individually to provide feedback on their work. Work with students to determine whether the gaps in their explanations are the result of inadequate attention to detail or a lack of understanding. In the latter case, work with students individually or in small groups to revisit the physical model of the windmill to talk through each key concept, guiding students to add them to their explanation and models during this discussion.

Land 3 minutes

Have students recall what they have learned about windmills, and discuss the following questions to reflect on energy and the environment.

▸ Do you think windmills are a good way to generate electricity? Why?

- *I think so because wind blows anyway, so windmills are an easy way to generate electricity.*
- *I think they are better than other ways to generate energy, like drilling or building a dam.*

▶ What impacts do you think windmills have on the environment?

- *The windfarm we saw took up a lot of space. If the windmills were on land, you might have to cut down lots of trees.*
- *You have to get the materials to build windmills from somewhere, so that might be bad for the environment.*

Tell students that in the next lesson, they will use their knowledge of energy to create their own devices to transfer and transform energy. Like William, they will design devices to solve a problem. Share the next lesson's Phenomenon Question: **How can we apply our knowledge of energy to solve a problem?**

Lessons 17–23
Engineering Challenge

Prepare

Throughout the module, students worked to build a shared understanding of energy, energy transfer, and energy transformation. In Lessons 17 through 23, students apply that knowledge to solve a problem in an engineering challenge. After reviewing the engineering design process, students identify an available energy source, a desired application of energy, and the materials available to propose a solution. Students then apply what they have learned about energy transfer and transformations to design a device that transforms energy from an available form into the desired form, emulating William Kamkwamba. In Lesson 23, students present final designs to their peers. The engineering challenge should take approximately seven days, but the duration may vary based on the time allotted for design revision, testing, and group presentations.

Application of Concepts

Task

Engineering Challenge

Phenomenon Question

How can we apply our knowledge of energy to solve a problem?

Student Learning

Knowledge Statement

The engineering design process can be used to create a device to transfer energy and transform it from an available form into the desired form.

Objective

- Lessons 17–23: Apply the engineering design process to construct and refine a device that transforms energy.

Texas Essential Knowledge and Skills Addressed

4.2A **Plan and implement descriptive investigations, including asking well defined questions, making inferences, and selecting and using appropriate equipment** or technology **to answer his/her questions.** (Addressed)

4.2E **Perform repeated investigations to increase the reliability of results.** (Addressed)

4.2F **Communicate** valid **oral and written results** supported by data. (Addressed)

4.3B **Represent the** natural **world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)

4.3C **Connect grade-level appropriate science concepts with** the history of science, **science careers, and contributions of scientists.** (Addressed)

4.6A **Differentiate among forms of energy, including mechanical,** sound, **electrical, light,** and thermal. (Addressed)

4.6C **Demonstrate that electricity travels in a closed path, creating an electrical circuit.** (Addressed)

English Language Proficiency Standards Addressed

3E Share information in cooperative learning interactions.

3F Ask and give information ranging from using a very limited bank of high-frequency, high-need, concrete vocabulary, including key words and expressions needed for basic communication in academic and social contexts, to using abstract and content-based vocabulary during extended speaking assignments.

Materials

		Lesson 17	Lesson 18	Lesson 19	Lesson 20	Lesson 21	Lesson 22	Lesson 23
Student	Science Logbook (Lesson 17 Activity Guides A and B)	●	●	●	●	●	●	●
	Engineering Challenge (per group): pinwheels (from Lesson 1), LED, 2 alligator clips, cardboard generator (from Lesson 14), supplies from home (e.g., plastic bottles, plastic or paper plates, straws, paper or polystyrene cups, wooden skewers, craft sticks)		●	●	●	●	●	●
	Science Logbook (Lesson 22 Activity Guide)						●	
Teacher	*The Boy Who Harnessed the Wind* by William Kamkwamba and Bryan Mealer (2010)	●						
	Engineering Design Process chart (Lesson 17 Resource)	●						
	Anchor chart, anchor model		●					
	Driving question board							●
Preparation	None							

Lesson 17

Objective: Apply the engineering design process to construct and refine a device that transforms energy.

Agenda

Launch (2 minutes)

Learn (28 minutes)

- Review the Engineering Design Process (13 minutes)
- Discuss How William Used the Engineering Design Process (15 minutes)

Land (15 minutes)

- Prepare for the Engineering Challenge (10 minutes)

Launch 2 minutes

Ask students to review the Phenomenon Question for this lesson: **How can we apply our knowledge of energy to solve a problem?**

Tell students that in the coming lessons, they will develop their own solution to a problem. In this lesson, they will first study how William Kamkwamba used the engineering design process.

Learn 28 minutes

Review the Engineering Design Process 13 minutes

Remind students that in the last module, they discussed the engineering design process and learned how the Wright brothers applied the process to design the first airplane.

Ask students to recall the steps in the process. Have students write their responses on sticky notes and place the notes on the board. The specific words and the order of the sticky notes do not matter yet. Once students finish discussing the steps of the process, have the class recreate the process by grouping and rearranging the sticky notes. Once the class has come to an agreement, have students review the engineering design process (Lesson 17 Resource or Lesson 17 Activity Guide A) and compare it to the process they developed. Discuss the similarities and differences as a class, and then ask the following question:

▸ In this process, why are the arrows pointing in two directions?
  - *To show that you can go back and forth between steps.*
  - *Sometimes you have to go back to an earlier step when something doesn't work.*
  - *Sometimes someone else's idea makes you rethink your design.*

Students must understand that although this process has both linear and circular aspects, it is more like a web with an input and an output. Engineers may take different paths through the engineering design process to solve problems and repeat steps until the solutions meet all criteria and constraints; however, there is always a starting point (a problem) and an ending point (a solution or device).

Discuss How William Used the Engineering Design Process 15 minutes

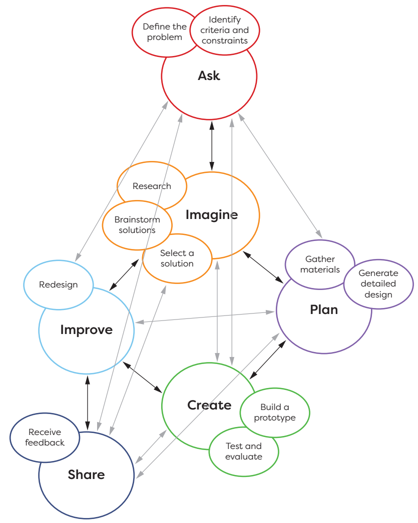
In the last lesson, students revisited the story of William Kamkwamba and how he built a windmill to generate electricity for his home. They discussed the problem William was trying to solve and how he solved the problem.

Have students pretend they are William and brainstorm the questions that he must have asked and the steps he took to design the solution to a problem. Use *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010) as a reference to show the engineering design process in action. Reread sections of the book as needed. Have students write their ideas on sticky notes and place the notes under the appropriate heading in the class-developed process.

As a class, discuss William's process as described in the book. Allow students to discuss steps that could go in two categories and explain why.

Differentiation

For students who would benefit from a visual aid, display the engineering design process (Lesson 17 Resource) and draw arrows from each step to the others. Sample arrows are shown below.



Spotlight on Knowledge and Skills

William's village experienced a year with very little rain. Without access to water, the crops could not grow. This need drove William's desire to develop a solution to their water shortage.

▶ Where in the process do you think William had to repeat steps a few times?

- *I bet his first windmill didn't work, so he had to imagine, create, and improve a lot.*
- *He probably had a lot of questions as he was putting the windmill together, and he had to be really creative with his materials. I bet he had to imagine and plan a few times to make it work better.*

▶ Do you think William worked alone?

- *His friends helped him build the first windmill.*
- *I bet his family and some people in the village helped him gather supplies.*
- *He probably asked people questions about different parts and how to use them.*

Explain that engineers and scientists often work in teams to accomplish their goals.

Check for Understanding

Use student responses while discussing William's design process to ensure that students understand the steps and nature of the process.

Evidence

Look for evidence that students understand how William used a process similar to the one shown in the engineering design process chart to solve his problem.

Next Steps

Students will gain additional experience with the engineering design process by participating in the engineering challenge. Support students as needed by referring to the engineering design process throughout the engineering challenge.

Land 15 minutes

Have students review what they learned about William and his windmill in preparation for their own engineering challenge, and then ask the following question:

Spotlight on Knowledge and Skills

Ask students to think back to the wind farm photograph from Lesson 3 (Lesson 3 Resource B). Explain that building a windfarm requires engineers and scientists with many different backgrounds, such as physicists, aerospace engineers, electrical engineers, mechanical engineers, wind turbine technicians, materials engineers, environmental scientists, industrial engineers, quality engineers, meteorological technicians, and many more.

▶ **How did William use the engineering design process to solve a problem?**

- *He figured out what problems he needed to solve. Then he read lots of books from the library to research and brainstorm solutions.*
- *He made different types of windmills with different materials and improved them each time.*
- *He shared his work with other people in his village.*

While discussing students' responses, emphasize the importance of planning, persistence, and teamwork. Encourage students to use those approaches in their own engineering challenge during the next lesson.

Prepare for the Engineering Challenge 10 minutes

To further prepare for the engineering challenge, ask students what they know about floods. Briefly discuss recent floods, either occurring locally or in other states. Display an image that shows a flood around people's homes, such as the following photograph taken by the Federal Emergency Management Agency (FEMA) in Houston, TX, after Hurricane Harvey (2017): http://phdsci.link/1016.

▶ **Imagine this scenario: You live in an area that has flooded and the power has gone out. You need some light to gather supplies and make sure your family is safe. Can you design something to solve this problem?**

Tell students they will be following in William's footsteps to develop and refine a device that transforms energy. Remind students that William went to the library to gather as much information as he could before he designed a working windmill. Explain that students have had the opportunity to learn about energy in the class, so they have gathered information to help them design a solution to their problem, just like William.

Remind students that it is important to identify the criteria and constraints of a design problem in the Ask stage of the engineering design process. As a class, develop the criteria and constraints that their solutions to the problem must meet.

▶ **What problem must our design be able to solve?**

- *We aren't able to see, so we need to find a way to see in the dark.*
- *We need to design a light so that people in our families can see where they are going.*

Teacher Note

If necessary, review the meanings of the terms *criteria* and *constraints* that were introduced to students in the Earth Features module.

Criteria: what is needed; what the requirements are

Constraints: what is possible; what the limitations are

▶ Using what you have learned about energy, how will you do that?

- *We need to make something that transfers energy from wind or another source to make something move.*
- *We will need a generator to transform mechanical energy into electrical energy.*
- *We need a light that can be powered by electrical energy.*

Explain that students will use the criteria for meeting this challenge to create a device that must successfully transfer and transform energy to produce light.

▶ What limitations or restrictions should be put on this device?

- *It can't be too big because we need to be able to carry it.*
- *We can only use materials that we have at home and in the class.*

Discuss that the criteria for possible solutions is that the device must successfully transfer and transform energy to produce light. Then agree that the constraints are that the device must fit in the classroom and be constructed using only a combination of materials from class and reused materials from home.

Have students record these criteria and constraints in the Ask section of their Science Logbooks (Lesson 17 Activity Guide B).

Work with students to develop a list of the materials they have access to from their work during the module. The list should include pinwheels from Lesson 1, LEDs, alligator clips, materials from previous investigation stations, and cardboard generators from Lessons 12–14. Explain that students may also use disposable or reused materials from home (e.g., cardboard boxes or tubes, plastic cups, straws, tape, string, craft sticks, wooden skewers). Students may not use electric-powered devices (e.g., electric fans) or gas- or battery-powered generators from home.

Ask students to consider how they could use available materials to construct a device that transforms energy. Now that students know the problem their device must solve, allow to them bring more materials from home they might want to use.

Teacher Note

Throughout the Engineering Challenge, encourage students to identify and demonstrate ways to reuse and conserve materials, such as reusing wooden skewers, plastic bottles, and plastic plates (4.1B).

Spotlight on Knowledge and Skills

As students discuss the criteria and constraints, acknowledge that there are many factors that will influence the design of their devices, and that each group will come up with different solutions. Encourage students to think about the resources available to them, how the area may have changed after a flood, and how these two factors will affect their designs.

Lesson 18

Objective: Apply the engineering design process to construct and refine a device that transforms energy.

Agenda

Launch (3 minutes)

Learn (40 minutes)

- Imagine a Design Solution (15 minutes)
- Plan a Design Solution (25 minutes)

Land (2 minutes)

Launch 3 minutes

On the first day of the engineering challenge, review this lesson's Phenomenon Question: **How can we apply our knowledge of energy to solve a problem?** Then, ask students to recap the problem they must solve.

Review class expectations for group work, and then divide students into groups.

Teacher Note

Consider using the same groups from Lessons 12–14 so that students may use the generators they developed in those lessons without conflict (3E).

Learn 40 minutes

Imagine a Design Solution 15 minutes

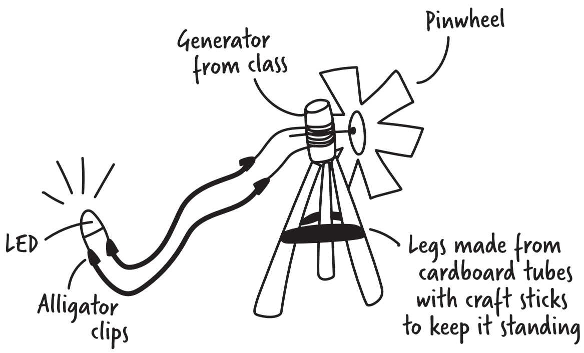
Draw students' attention to the anchor model and anchor chart. Encourage groups to use their knowledge of energy as they brainstorm how to build their devices.

Groups brainstorm solutions and select an idea, recording their thoughts in the Imagine section of their Science Logbooks (Lesson 17 Activity Guide B). To select an idea, students should compare their ideas and identify the one that best meets the specified criteria and constraints.

Plan a Design Solution 25 minutes

After groups select an idea, have them create a diagram and a list of needed materials in the Plan section of their Science Logbooks. Responses will vary by group.

Sample diagram:



Sample student responses (Lesson 17 Activity Guide B):

What materials will you need to transform energy to produce light?

- *We will need a generator like the one we made.*
- *We will need an LED so we know if we have generated light.*

What materials will you need to transfer energy to the desired place?

- *We will need alligator clips like we used in our model.*
- *We could use a solar panel.*

What other materials will you need?

- *A pinwheel*
- *Glue or tape to connect the pinwheel to the nail*
- *Three paper towel tubes*
- *A cardboard box*

Gather students to provide peer feedback. Allow each group to share their diagram and materials list with another group. Peers should listen, ask questions, and offer suggestions. Encourage students to ask questions such as these: Can you say more about that? How did you arrive at that conclusion? How do you plan to _______?

Land 2 minutes

Allow students to regroup and discuss what specific materials each team member should bring from home so they are prepared to build their devices during the next lesson.

English Language Development

As students provide feedback to their classmates on their designs, sentence frames like the following may be beneficial (3F):

- Can you tell us why you chose _______?
- How do you plan to _______?

Lesson 19

Objective: Apply the engineering design process to construct and refine a device that transforms energy.

Agenda

Launch (3 minutes)

Learn (40 minutes)

- Create a Design Solution (40 minutes)

Land (2 minutes)

Launch 3 minutes

Ask students to get into their engineering challenge groups and discuss where they are in the engineering design process. Remind students that the process is flexible and that they may need to go back to a previous stage as they continue to work.

Learn 40 minutes

Create a Design Solution 40 minutes

Tell groups to begin building their devices. After groups have built their devices, have students respond to the questions in the Create section of their Science Logbooks (Lesson 17 Activity Guide B). Responses will vary by group.

Differentiation

As students build their device over the next several lessons, it may be helpful for them to fulfill particular roles within their groups. These roles can rotate daily. Suggested group roles are shown below (3E).

- Team Leader
- Scribe
- Time Keeper
- Builders

Sample student responses (Lesson 17 Activity Guide B):

What works well?

- *The pinwheel spins.*
- *The light stays on when we quickly spin the magnets in the generator.*

What needs improvement?

- *The LED doesn't light up yet.*
- *We need to figure out why the light doesn't turn on. Maybe the wires are connected the wrong way.*
- *We need to make the magnets in the generator spin faster so the light is brighter and stays on longer.*

As needed, prompt students with questions such as the following: Does your device work? Does your device solve the problem? Is the light bright or dim? Is a little or a lot of energy being put into the system?

Land

2 minutes

Allow students to brainstorm what additional materials they might need to bring from home to improve their devices. Students should plan to bring any new materials for the next lesson.

Lesson 20

Objective: Apply the engineering design process to construct and refine a device that transforms energy.

Agenda

Launch (3 minutes)

Learn (40 minutes)

- Provide Peer Feedback (10 minutes)
- Improve a Design Solution (30 minutes)

Land (2 minutes)

Launch 3 minutes

Ask students to rejoin their groups and set up their devices to share with their peers. Explain that students will participate in a Gallery Walk for groups to share ideas.

Differentiation

Use a Chalk Talk instead of a Gallery Walk if students would benefit from more individual processing time (3E).

Learn 40 minutes

Provide Peer Feedback 10 minutes

Have students circulate to view and try other groups' devices. They should leave any relevant feedback on sticky notes. Remind students to leave the devices as they found them. Students should discuss the following questions as they circulate:

- How well does this design meet the criteria and constraints?
- How is this design similar to and different from our design?
- What suggestions can we leave for this team to make improvements?
- What ideas does this design give us for improving our design?

Differentiation

Consider providing sentence frames to support English learners and striving writers as they give feedback. For example, "To help fix ______ , try ______ ." (3F)

Check for Understanding

Observe feedback comments and steps that groups take to improve their designs.

Evidence

Looks for evidence that all students

- suggest how to make energy transfer more efficiently or suggest other forms of energy that could be transformed, and
- understand energy transfer and transformation and how to improve their devices.

Next Steps

If students have difficulty providing feedback that includes a suggestion, provide the following sentence frame:

- The design could be improved by _______.

As groups begin improving their devices, consider pairing groups that have difficulty using feedback with students who suggested helpful feedback or who implemented similar changes successfully.

Improve a Design Solution 30 minutes

Next, groups return to their own devices, review their peer feedback, and begin the Improve section in their Science Logbooks by answering the first question. Responses will vary by group.

Sample student responses (Lesson 17 Activity Guide B):

What will you change about your device? How do you predict those changes will affect the device's performance?

- *We want to see if it is possible to get the magnets in the generator to spin faster.*
- *We need to find a way to make the pinwheel keep spinning.*
- *We want to fix the base of our windmill to make it more stable.*

Throughout this process, groups should discuss improvements, adjust their designs, create new versions of their devices, and retest them. Have students document their improvements and findings in the table in their Science Logbooks. Remind students that the engineering design process is iterative, and they may need to revisit an earlier stage of the process. Encourage students to return to the Plan, Create, and Improve stages of the process until they are satisfied with their design.

Land

2 minutes

Allow students to brainstorm what additional materials they might need to bring from home to make further improvements to their devices. Students should plan to bring any new materials for the next lesson.

Lesson 21

Objective: Apply the engineering design process to construct and refine a device that transforms energy.

Agenda

Launch (5 minutes)

Learn (38 minutes)

- Improve a Design Solution (38 minutes)

Land (2 minutes)

Launch 5 minutes

Begin the class by asking students to briefly discuss their responses to the questions below.

- ▶ Where are you in the engineering design process?
- ▶ What is going well in your group's process?
- ▶ How can you improve your group's process?

Explain that groups will continue to optimize their devices. Then, each group will have time to plan a presentation for sharing their final device with the class in the next lesson.

Differentiation

If students need support reflecting on the engineering design process, review Lesson 17 Activity Guide A. Ask students to identify the part of the visual that describes their current tasks. Then, ask students to identify the stages they have completed and to consider what has gone well and what needs improvement within those stages (3F).

Learn 38 minutes

Improve a Design Solution 38 minutes

Groups should continue to make improvements to their designs, create new versions of their devices, and retest them. Have students document their improvements and findings in the table in their Science Logbooks. Remind students that the engineering design process is iterative, which means they should return to the Plan, Create, and Improve stages of the process until they are satisfied with their design.

Land 2 minutes

Tell students that during the next lesson, their groups will have a few minutes to finalize their design. Then, each group will prepare a presentation to share their final design to the class.

Lesson 22

Objective: Apply the engineering design process to construct and refine a device that transforms energy.

Agenda

Launch (2 minutes)

Learn (42 minutes)

- Improve a Design Solution (7 minutes)
- Prepare to Share a Design Solution (35 minutes)

Land (1 minute)

Launch 2 minutes

Explain that each group should agree on their final design and then plan a presentation to share their device with the class.

Learn 42 minutes

Improve a Design Solution 7 minutes

Groups agree on final design to present to the class and make any necessary minor adjustments.

Prepare to Share a Design Solution 35 minutes

Explain that scientists and engineers present their work in a variety of ways, including speeches, visual presentations, videos, websites, and published articles. Work with students to determine which methods of presentation will work best considering the time and resources available in the classroom.

Introduce students to the engineering challenge rubric in their Science Logbooks (Lesson 22 Activity Guide), and discuss student questions about the presentation criteria. Give groups time to plan their presentations, create their final diagrams, and record this information in the Share section of their Science Logbooks (Lesson 17 Activity Guide B).

Land

1 minute

Remind students that during the next lesson, their groups will be presenting their designs to the class. Ask students to determine how each group member will contribute to the presentation.

English Language Development

English learners would likely benefit from additional time and support to prepare for the oral presentation of the group design. Provide students with time to rehearse each part of the presentation before the whole class presentation. Consider allowing students time to write their answers to the questions from the rubric on notecards prior to the presentation (3E).

Lesson 23

Objective: Apply the engineering design process to construct and refine a device that transforms energy.

Agenda

Launch (2 minutes)

Learn (38 minutes)

- Share a Design Solution (38 minutes)

Land (5 minutes)

Launch 2 minutes

Allow groups a few minutes to prepare for their presentations.

Learn 38 minutes

Share a Design Solution 38 minutes

Gather the class to listen to each group's presentation. Allow groups to demonstrate their devices during their presentations. Tell students to consider the rubric criteria in their Science Logbooks (Lesson 22 Activity Guide) as they listen.

After each presentation, students should write feedback for the group on sticky notes or half sheets of paper in response to this prompt:

▸ **Considering the rubric criteria, identify one strength of this group's presentation and one idea for improvement.**

Each time students respond to the prompt, collect the written feedback from the class before the next group presents. After all groups have presented, distribute the feedback to each group. Give students time to review the feedback and ask questions before turning it in.

Land 5 minutes

Revisit the Phenomenon Question **How can we apply our knowledge of energy to solve a problem?** Discuss students' reflections on this process. Ask questions such as the following to guide the discussion:

- ▸ How did you apply your knowledge of energy to solve a problem?
  - *We needed to see in our houses during a power outage, so we used what we learned in class about windmills to transform energy from wind into light, like William.*
  - *We built a device that transfers and transforms energy.*
- ▸ What knowledge of energy was most useful in designing your device?
  - *Since we learned about different energy transformations, we knew we could use one energy source and change it to produce light.*
  - *Knowing that energy is transferred in different ways helped us design a device to move energy from one place to another.*

Explain that students will summarize their understanding of the Essential Question, **How do windmills change wind to light?**, and apply this new knowledge in an End-of-Module Assessment in subsequent lessons.

Spotlight on Knowledge and Skills

Help students reflect on the relationship between science, engineering, and technology. Engineers apply relevant scientific knowledge to improve or develop technologies that solve problems in society.

Lessons 24–26
Windmills at Work

Prepare

In Lessons 24 through 26, students synthesize their learning from throughout the module and articulate their understanding of energy in a Socratic Seminar and End-of-Module Assessment. In Lesson 24, students discuss the Essential Question in a Socratic Seminar and capture their thoughts in writing. They briefly revisit the driving question board to reflect on their progress and then individually complete the End-of-Module Assessment in Lesson 25. During the End-of-Module Assessment, students apply their knowledge of patterns and systems to construct explanations about energy, how it transfers from place to place, and how it transforms. In this module's culminating lesson, Lesson 26, students debrief the assessment and look ahead to the next module.

Application of Concepts

Task

Socratic Seminar

End-of-Module Assessment

Phenomenon Question

How do windmills change wind to light? (Essential Question)

Student Learning

Knowledge Statement

In a system, specific indicators of energy can be generated through energy transfers and transformations.

Objectives

- Lesson 24: Explain changes in a system as the transfer and transformation of energy. (Socratic Seminar)
- Lesson 25: Explain changes in a system as the transfer and transformation of energy. (End-of-Module Assessment)
- Lesson 26: Explain changes in a system as the transfer and transformation of energy. (End-of-Module Assessment Debrief)

Texas Essential Knowledge and Skills Addressed

4.2C **Construct** simple tables, charts, bar graphs, and **maps** using tools and current technology **to organize**, examine, and evaluate data. (Addressed)

4.2D **Analyze data and interpret patterns to construct reasonable explanations** from data **that can be observed** and measured. (Addressed)

4.2F **Communicate valid oral and written results supported by data.** (Addressed)

4.3B **Represent the** natural **world using models** such as the water cycle and stream tables and identify their limitations, including accuracy and size. (Addressed)

4.6A **Differentiate among forms of energy, including mechanical, sound, electrical, light, and thermal.** (Mastered)

4.6C **Demonstrate that electricity travels** in a closed path, **creating an electrical circuit**. (Mastered)

English Language Proficiency Standards Addressed

2F Listen to and derive meaning from a variety of media such as audio tape, video, DVD, and CD ROM to build and reinforce concept and language attainment.

3G Express opinions, ideas, and feelings ranging from communicating single words and short phrases to participating in extended discussions on a variety of social and grade-appropriate academic topics.

Materials

		Lesson 24	Lesson 25	Lesson 26
Student	Science Logbook (Lesson 24 Activity Guides A, B, and C)	●		
	End-of-Module Assessment		●	
	End-of-Module Assessment Rubric			●
	Sample of End-of-Module Assessment responses that meet expectations (either sample responses from Teacher Edition or sample from class)			●
Teacher	Anchor chart	●		●
	Anchor model	●		
	Driving question board		●	●
Preparation	Score End-of-Module Assessments and write individual feedback.			●
	Select End-of-Module Assessment responses to share with students.			●
	Prepare visual for student connections between module learning and content standards (see Lesson 26 Resource).			●

Lesson 24

Objective: Explain changes in a system as the transfer and transformation of energy. (Socratic Seminar)

Agenda

Launch (7 minutes)

Learn (33 minutes)

- Prepare for Socratic Seminar (8 minutes)
- Engage in Socratic Seminar (25 minutes)

Land (5 minutes)

Launch 7 minutes

Students make a relationship map to show connections among key terms learned throughout the module. To start the map, they cut out the key terms in their Science Logbook (Lesson 24 Activity Guide A). Individually, students arrange the terms in their Science Logbooks to show the term relationships. They can draw arrows or other symbols and write words between the terms to express the relationships. Once students organize the map, they can glue the terms in place.

Learn 33 minutes

Prepare for Socratic Seminar 8 minutes

Tell students they will share their understanding of the Essential Question with one another through a Socratic Seminar discussion. First, students write an initial response to the Essential Question: **How do windmills change wind to light?** in their Science Logbooks (Lesson 24 Activity Guide B) as a Quick Write. When students finish, ask them to draw a line below their response. At the end of the seminar, students will revisit this response to see how their thoughts have changed.

Content Area Connection: English

This Socratic Seminar allows students to use their speaking and listening skills to express and deepen their science content knowledge. In a Socratic Seminar, students prepare for and participate in a collaborative, evidence-based, academic conversation. See the Socratic Seminar resource in the Implementation Guide for more background (3G).

In this discussion, students should work toward grade-level expectations for speaking and listening.

Engage in Socratic Seminar 25 minutes

As needed, review the routines and expectations for participating effectively in a Socratic Seminar, including classroom guidelines and resources for speaking and listening. Have students review the collaborative conversation strategies in their Science Logbooks (Lesson 24 Activity Guide C). Explain that this resource reminds students of different ways they can participate in a collaborative conversation and provides sentence frames to support student participation. Instruct students to choose one or two conversation strategies to use as a visual reminder of effective ways to contribute to the discussion and to cut out or circle those strategies as a visual reminder.

Remind students that during the seminar they should incorporate science terminology learned during the module. Students can refer to their relationship map from this lesson's Launch, the anchor chart, the anchor model, and other classroom resources to support their discussion.

Display and read aloud the Essential Question to prompt the discussion: **How do windmills change wind to light?**

Students discuss the question. In the Socratic Seminar, students respond to one another directly, with minimal teacher facilitation. Students can remind one another of conversation norms, ask for evidence, and pose questions to extend the conversation.

As needed, step in briefly to reinforce norms for collaborative conversations. Consider posing one or two questions midway through the seminar to spur additional conversation, such as the following:

- How is William's windmill similar to and different from the other windmills we saw in photographs and paintings?
- How could a windmill work on days with little wind?
- What phenomena have you experienced that can be explained through energy transfers and transformations?

English Language Development

English learners may benefit from having a word bank available to use as they participate in the Socratic Seminar discussion. Include words and phrases such as *energy transfer*, *transform*, *windmill*, *generate*, *wind*, *speed*, *distance*, *indicators of energy* (i.e., *sound*, *light*, and *movement*), *collide*, and *electricity*.

Check for Understanding

As students engage in the Socratic Seminar, take notes on their participation, content knowledge, and use of scientific language. To monitor student participation and the flow of the conversation, consider writing each student's name around the edge of a piece of paper before the lesson and drawing lines between speakers during the conversation.

Evidence

Listen for evidence that students

- describe energy transfers in and around the windmill system,
- describe energy transformations as changes in the indicators of energy (e.g., moving air, moving windmill blades, sound, electricity, light, changes in temperature), and
- use precise language such as *energy*, *transfer*, and *transformation*.

Next Steps

If students express misconceptions about energy, meet with them individually or in a small group before the End-of-Module Assessment. Provide additional hands-on investigation of phenomena related to their misunderstanding, and help students use precise language to construct explanations of those phenomena.

Land 5 minutes

Students reread their Quick Write from the beginning of the lesson. Below the line, they summarize how the Socratic Seminar reinforced or changed their thinking. Encourage students to share examples of how their thinking evolved during the discussion.

Explain that in the next lesson students will apply their understanding of energy in an End-of-Module Assessment.

Lesson 25

Objective: Explain changes as the transfer and transformation of energy. (End-of-Module Assessment)

Agenda

Launch (8 minutes)

Learn (35 minutes)

- Complete the End-of-Module Assessment (35 minutes)

Land (2 minutes)

Launch 8 minutes

Provide an example of energy transfers or transformations for students: turn the classroom lights off and on, slide a textbook across a table, or flip a water bottle in the air. Ask students to Think–Pair–Share about the following prompts.

▶ How do you think people without an understanding of energy would describe what happened?

- *The textbook moved because you used your arm to push it.*
- *The light switch turned the lights on.*
- *The water bottle flipped because you threw it in the air.*

▶ Using what you know now about energy, describe what happened.

- *When you pushed the book, energy from your arm transferred to the book because I saw it slide across the table. The energy from your arm transformed into mechanical energy, a different kind of energy.*
- *When you flipped the light switch, you caused energy to travel through a wire and to the light bulb. The light bulb transforms electrical energy into light.*
- *When you flipped the water bottle, you transferred the energy from your hand to the bottle, and you transformed the energy from your arm into mechanical and sound energy.*

Return to the driving question board, and ask students to share reflections on how their understanding of energy has grown since applying what they have learned in this module.

Ask students to share any new questions that might lead to future investigations.

Teacher Note

Display the driving question board with the anchor chart and anchor model to help students make connections.

Extension

Students can research or investigate these questions independently at work stations or as optional homework.

Learn 35 minutes

Complete the End-of-Module Assessment 35 minutes

Prepare students for the End-of-Module Assessment by explaining that the assessment is a way for them to show all the knowledge they have developed through their study of energy. Remind students to provide detailed explanations and to use the resources posted in the room if needed.

Distribute the End-of-Module Assessment. Read aloud the assessment items. Students complete the End-of-Module Assessment individually. If needed, provide additional time for students to finish.

Teacher Note

To prepare for the next lesson, review End-of-Module Assessment responses to provide rubric scores and actionable feedback to students on a separate page from the assessment. (See the rubric and sample responses in the End-of-Module Assessment section of this book.) In the next lesson, students review their own assessment responses and then the teacher feedback. Also, select an exemplar student response to share with students, or plan to share the sample student responses provided in the Teacher Edition. If selecting student responses, remember to remove identifying information and to select diverse student responses.

When providing feedback, be sure to guide students to focus on specific areas of improvement to deepen their understanding of module concepts. For students who need remediation, offer opportunities to revisit portions of the module.

Differentiation

Provide an audio recording of the assessment items for students who need additional reading support (2F).

Land 2 minutes

Tell students that in the next lesson they will share their thinking about the End-of-Module Assessment questions.

Lesson 26

Objective: Explain changes as the transfer and transformation of energy. (End-of-Module Assessment Debrief)

Agenda

Launch (8 minutes)

Learn (32 minutes)

- Debrief the End-of-Module Assessment (17 minutes)
- Revise End-of-Module Assessment Responses (10 minutes)
- Reflect on Content Standards (5 minutes)

Land (5 minutes)

Launch 8 minutes

Explain that in this lesson, students will review the End-of-Module Assessment, discuss responses, and then have an opportunity to revise their answers. First, they will review the assessment rubric and assess their own responses to begin reflecting on their learning.

Share the End-of-Module Assessment rubric with students and distribute their individual responses (without teacher feedback, if possible). Students reflect on their own responses, recording their self-assessment feedback on their copy of the rubric.

Next, distribute written teacher feedback on students' End-of-Module Assessments. Students review the teacher feedback of their own responses independently and write on sticky notes any questions they want to discuss with the class. Students post their questions, either anonymously or with their names. Quickly review students' questions as they post them and plan which questions to discuss first.

Learn 32 minutes

Debrief the End-of-Module Assessment 17 minutes

Distribute copies of sample responses that meet expectations, one response per assessment item. Students compare the sample responses to the rubric criteria and annotate those responses with the evidence of each rubric criterion they demonstrate.

Discuss each assessment item, posing relevant student questions from the Launch. Provide sentence frames such as the following to encourage all students to participate in the discussion.

- In the sample response, I notice _______.
- That makes me wonder _______.
- That makes me realize _______.
- I thought _______. How does that relate to _______?
- I would add _______ because _______.

Discuss the remaining student questions. As needed, encourage students to review their Science Logbooks, the anchor model, the anchor chart, and other resources for evidence during the discussion.

Revise End-of-Module Assessment Responses 10 minutes

Students revise their End-of-Module Assessment responses by using a different color pen or pencil, applying new ideas from the debrief conversation to deepen their responses.

Reflect on Content Standards (5 minutes)

Show students the standards they focused on in this module and explain that standards are one tool teachers use to plan instruction. Read aloud each content standard, and ask students to point out evidence of related learning in their Science Logbooks, End-of-Module Assessment, or other resources.

Teacher Note

Depending on school and classroom guidelines and routines, decide whether to score and provide feedback on these revised responses.

Land

5 minutes

Students reflect on their learning by using a conversation routine, such as Mix and Mingle or Inside-Outside Circles. Ask questions such as the following, and have students switch discussion partners for each question.

- What do you want to teach others about energy?
- What else do you want to learn about energy?
- What helped you learn in this module?
- What do you hope to learn in the next module?

Optional Homework

Students compose a short message about energy to share with their family or community.

Student End-of-Module Assessment, Sample Responses, and Rubric

Name: ____________________ Date: ____________

LEVEL 4 ENERGY

End-of-Module Assessment

1. Imagine that you are in the kitchen helping to cook dinner and listening to music.

   Draw a model to show the indicators of energy that you would observe. Be sure to label your model, including the indicators of energy.

2. Use a pencil or a highlighter to analyze the data set below. Use the data set to answer the questions that follow.

Student A and Student B are curious about who can kick a soccer ball into a goal with more energy. They know that a slower ball will take more time to reach the goal. The students take turns kicking the ball from the same location and timing how long it takes for the ball to reach the goal. Their data set is displayed in the table below.

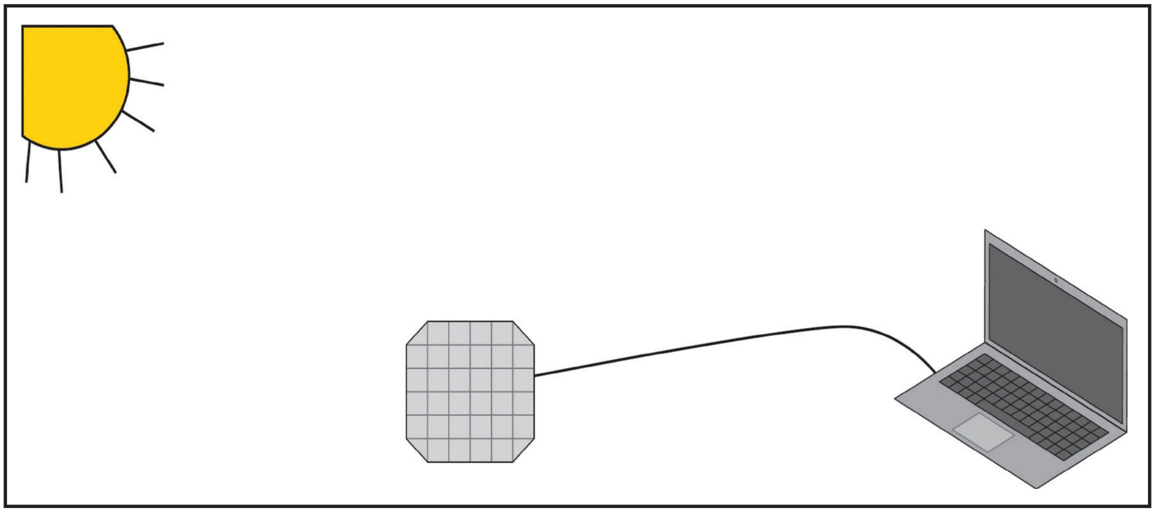
Trial	Time for Student A	Time for Student B
1	4 seconds	6 seconds
2	4.5 seconds	5 seconds
3	4 seconds	5.5 seconds
4	4.5 seconds	4 seconds
5	5 seconds	5 seconds
6	4 seconds	5.5 seconds
7	4.5 seconds	5 seconds
8	4.5 seconds	5 seconds
9	5.5 seconds	5.5 seconds
10	4.5 seconds	5 seconds

a. What pattern(s) do you notice in the data set? Use evidence from the data to support your response.

b. Neither student has ever worked with this type of information before. What three questions might the students have about this data as they try to figure out who kicked the soccer ball with more energy?

c. Student A says that she used more energy during the investigation than Student B. Is there evidence in the data to support her claim?

3. The model below shows a solar cell powering a laptop computer that is playing music. Add detailed information to the model to explain the energy transfers and energy transformations taking place.



4. A blue marble is sitting on a flat surface when a white marble collides with it. Describe what happens to the energy of each marble before, during, and after the collision. If needed, create a drawing in the box to help organize your thoughts.

Before the collision:

During the collision:

After the collision:

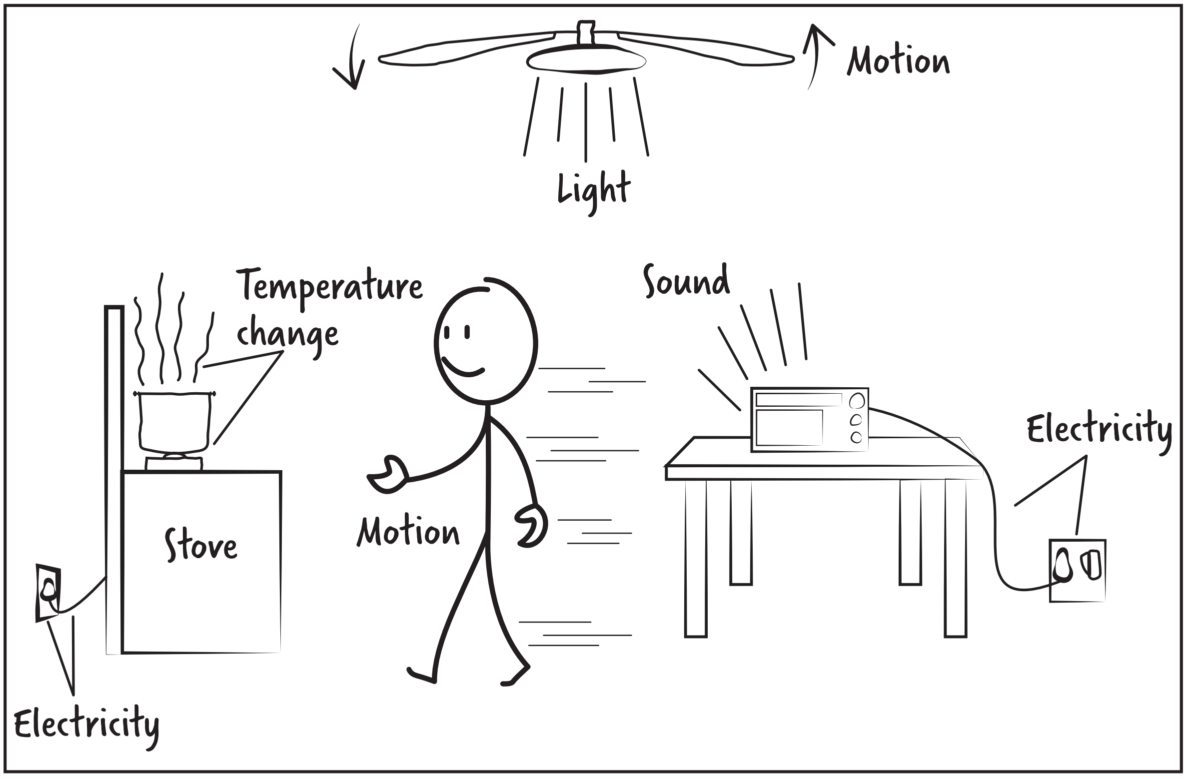
Name: Sample Date:

LEVEL 4 ENERGY

End-of-Module Assessment

1. Imagine that you are in the kitchen helping to cook dinner and listening to music.

   Draw a model to show the indicators of energy that you would observe. Be sure to label your model, including the indicators of energy.



2. Use a pencil or a highlighter to analyze the data set below. Use the data set to answer the questions that follow.

Student A and Student B are curious about who can kick a soccer ball into a goal with more energy. They know that a slower ball will take more time to reach the goal. The students take turns kicking the ball from the same location and timing how long it takes for the ball to reach the goal. Their data set is displayed in the table below.

Trial	Time for Student A	Time for Student B
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5	5 seconds	5 seconds
6	4 seconds	5.5 seconds
7	4.5 seconds	5 seconds
8	4.5 seconds	5 seconds
9	5.5 seconds	5.5 seconds
10	4.5 seconds	5 seconds

a. What pattern(s) do you notice in the data set? Use evidence from the data to support your response.

The pattern I see is that Student A almost always kicked the ball into the goal faster. I notice that Student A kicked the soccer ball into the goal faster 7 times, and Student B kicked it faster only once. The typical time for Student A was 4.5 seconds, and the typical time for Student B was 5.5 seconds.

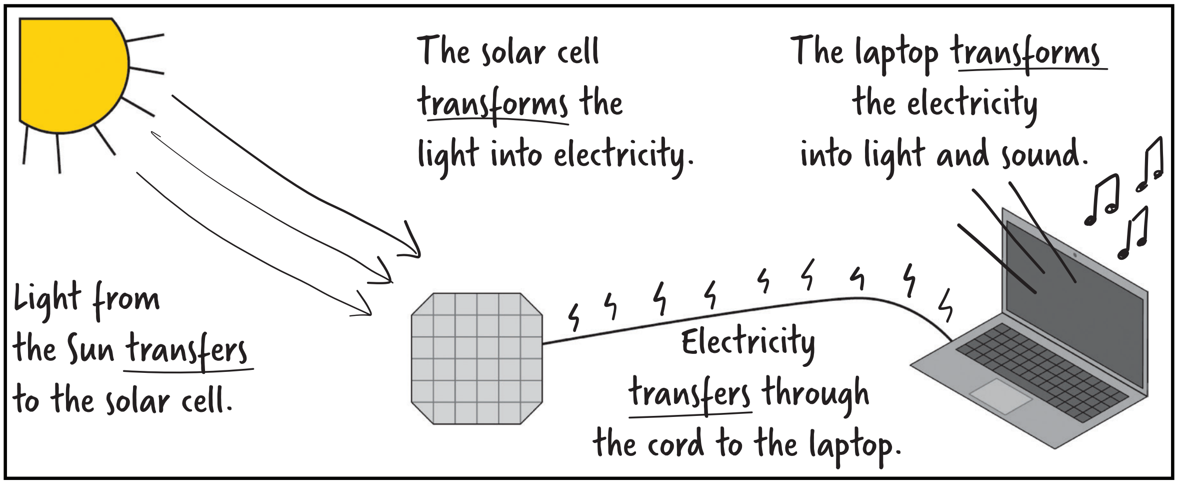
b. Neither student has ever worked with this type of information before. What three questions might the students have about this data as they try to figure out who kicked the soccer ball with more energy?

Why did Student B's ball get to the goal faster in Trial 4? Did Student B use more energy than Student A in Trial 4? How does the time it takes the ball to get to the goal relate to the energy used to kick it?

c. Student A says that she used more energy during the investigation than Student B. Is there evidence in the data to support her claim?

Yes. Since Student A got the soccer ball to the goal faster almost every time, her ball was usually moving faster and had more energy. I know this because I remember from the ball bearing investigation that an object with greater speed has more energy. Student A transferred energy to the ball each time she kicked it, so she used more energy during the investigation.

3. The model below shows a solar cell powering a laptop computer that is playing music. Add detailed information to the model to explain the energy transfers and energy transformations taking place.



4. A blue marble is sitting on a flat surface when a white marble collides with it. Describe what happens to the energy of each marble before, during, and after the collision. If needed, create a drawing in the box to help organize your thoughts.

Before the collision:

The blue marble doesn't have any energy of motion because it is sitting still. The white marble has energy because it is moving. It is also making a sound as it rolls.

During the collision:

The white marble hits the blue marble. We know some of the white marble's mechanical energy is transformed because we hear a sound and both marbles get a little warm. Some of the white marble's mechanical energy is transferred to the blue marble, causing it to move.

After the collision:

The blue marble starts moving because the force from the collision transferred mechanical energy to it. The white marble's motion changes, too, and eventually it stops.

LEVEL 4 ENERGY

End-of-Module Assessment Rubric

Item and Standards Addressed		1 **Incorrect or unreasonable response with no detail or evidence provided**	2 **Correct or reasonable response with no detail or evidence provided** **OR** **Incorrect or unreasonable response with some detail or evidence provided**	3 **Correct or reasonable response with some detail or evidence provided** **OR** **Incorrect or unreasonable response with sufficient detail or evidence provided**	4 **Correct or reasonable response with sufficient detail or evidence provided**
1	4.3B 4.6A	The student model includes one or two of the five energy indicators (electricity, temperature change, light, motion, sound) but does not represent them accurately. OR The student model does not include any energy indicators.	The student model includes and accurately represents one or two of the five energy indicators (electricity, temperature change, light, motion, sound). OR The student model includes three or four of the five energy indicators but does not represent them accurately.	The student model includes and accurately represents three or four of the five energy indicators (electricity, temperature change, light, motion, sound). OR The student model includes all five energy indicators but does not represent them accurately.	The student model includes and accurately represents all five energy indicators (electricity, temperature change, light, motion, sound).
2a	4.2D	The student does not correctly identify any patterns in the data set related to time, distance, speed, or energy and provides no detail or supporting evidence to justify the response.	The student correctly identifies a pattern in the data set related to time, distance, speed, or energy but provides no detail or supporting evidence to justify the response. OR The student does not correctly identify any patterns in the data set but provides some detail or supporting evidence to justify the response.	The student correctly identifies a pattern in the data set related to time, distance, speed, or energy and provides some detail or supporting evidence to justify the response.	The student correctly identifies a pattern in the data set related to time, distance, speed, or energy and provides clear supporting evidence to justify the response.

Item and Standards Addressed		1 **Incorrect or unreasonable response with no detail or evidence provided**	2 **Correct or reasonable response with no detail or evidence provided** **OR** **Incorrect or unreasonable response with some detail or evidence provided**	3 **Correct or reasonable response with some detail or evidence provided** **OR** **Incorrect or unreasonable response with sufficient detail or evidence provided**	4 **Correct or reasonable response with sufficient detail or evidence provided**
2b	**4.2A**	The student does not provide any questions. OR The student provides one or more questions that do not reveal the relationship between time, distance, speed, and energy.	The student provides one question that reveals the relationship between time, distance, speed, and energy.	The student provides two questions that reveal the relationship between time, distance, speed, and energy.	The student provides three questions that reveal the relationship between time, distance, speed, and energy.
2c	**4.2D**	The student's response is incorrect and provides no supporting evidence of the relationship between time, distance, speed, and energy.	The student's response is correct but provides no supporting evidence of the relationship between time, distance, speed, and energy. OR The student's response is correct despite obvious errors in data analysis. Some evidence of reasoning must be provided.	The student's response is correct but provides little supporting evidence of the relationship between time, distance, speed, and energy. OR The student's response is incorrect due to obvious errors in data analysis but provides some evidence of reasoning.	The student's response is correct and provides clear supporting evidence of the relationship between time, distance, speed, and energy.

Item and Standards Addressed		1 Incorrect or unreasonable response with no detail or evidence provided	2 Correct or reasonable response with no detail or evidence provided OR Incorrect or unreasonable response with some detail or evidence provided	3 Correct or reasonable response with some detail or evidence provided OR Incorrect or unreasonable response with sufficient detail or evidence provided	4 Correct or reasonable response with sufficient detail or evidence provided
3	4.3D 4.6A	The improved model shows only one of the four key components correctly (transfer of energy from the Sun to the solar cell, transformation of light into electrical energy, transfer of electrical energy through the cord, transformation of electrical energy into light and sound). OR The improved model does not show any key components.	The improved model shows only two of the four key components correctly (transfer of energy from the Sun to the solar cell, transformation of light into electrical energy, transfer of electrical energy through the cord, transformation of electrical energy into light and sound).	The improved model shows only three of the four key components correctly (transfer of energy from the Sun to the solar cell, transformation of light into electrical energy, transfer of electrical energy through the cord, transformation of electrical energy into light and sound).	The improved model shows all four key components correctly (transfer of energy from the Sun to the solar cell, transformation of light into electrical energy, transfer of electrical energy through the cord, transformation of electrical energy into light and sound).
4	4.2A	The student's response does not provide any detail about the energy of each marble before, during, or after the collision.	The student's response provides some detail about the energy of each marble before, during, or after the collision.	The student's response provides at least some detail about the energy of each marble before, during, and after the collision.	The student's response accurately describes what happens to the energy of each marble before, during, and after the collision.

Appendix A

Module Resources

Contents

LESSON 1 RESOURCE A

Windmill Gears Photograph

LESSON 1 RESOURCE B

Windmill Grinding Photograph

LESSON 2 RESOURCE

Windmill Model Setup Instructions

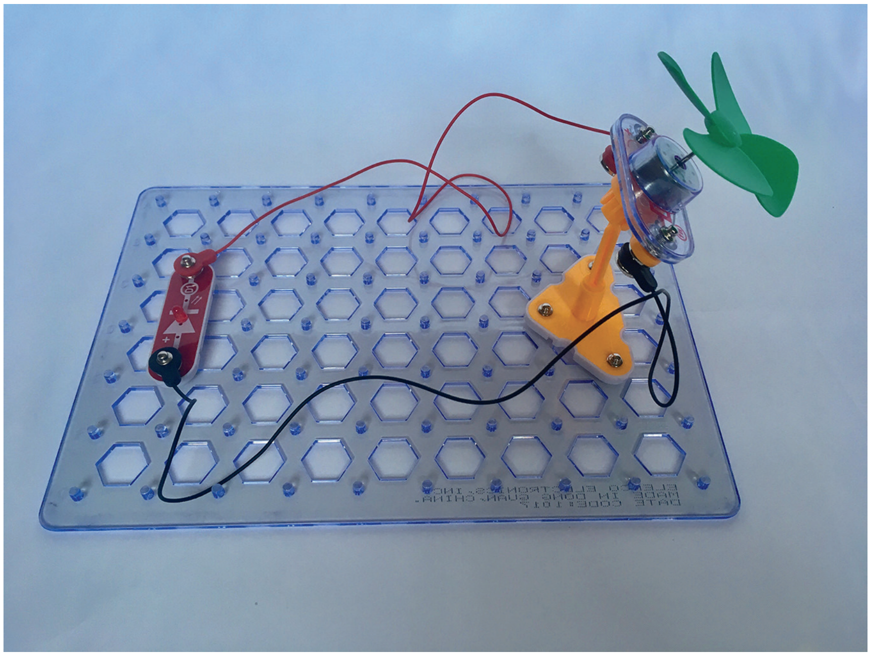
Materials and Preparation

Materials from Snap Circuits® Green kit by Elenco®: base grid, fan, motor, pivot stand base, pivot post, pivot top, black jumper wire, red jumper wire, red LED

Preparation: Place all materials at workstations. No additional setup is required.

Windmill Configuration

Students should work out (or use trial and error to arrive at) the configuration shown below. Exact placement of components may vary.

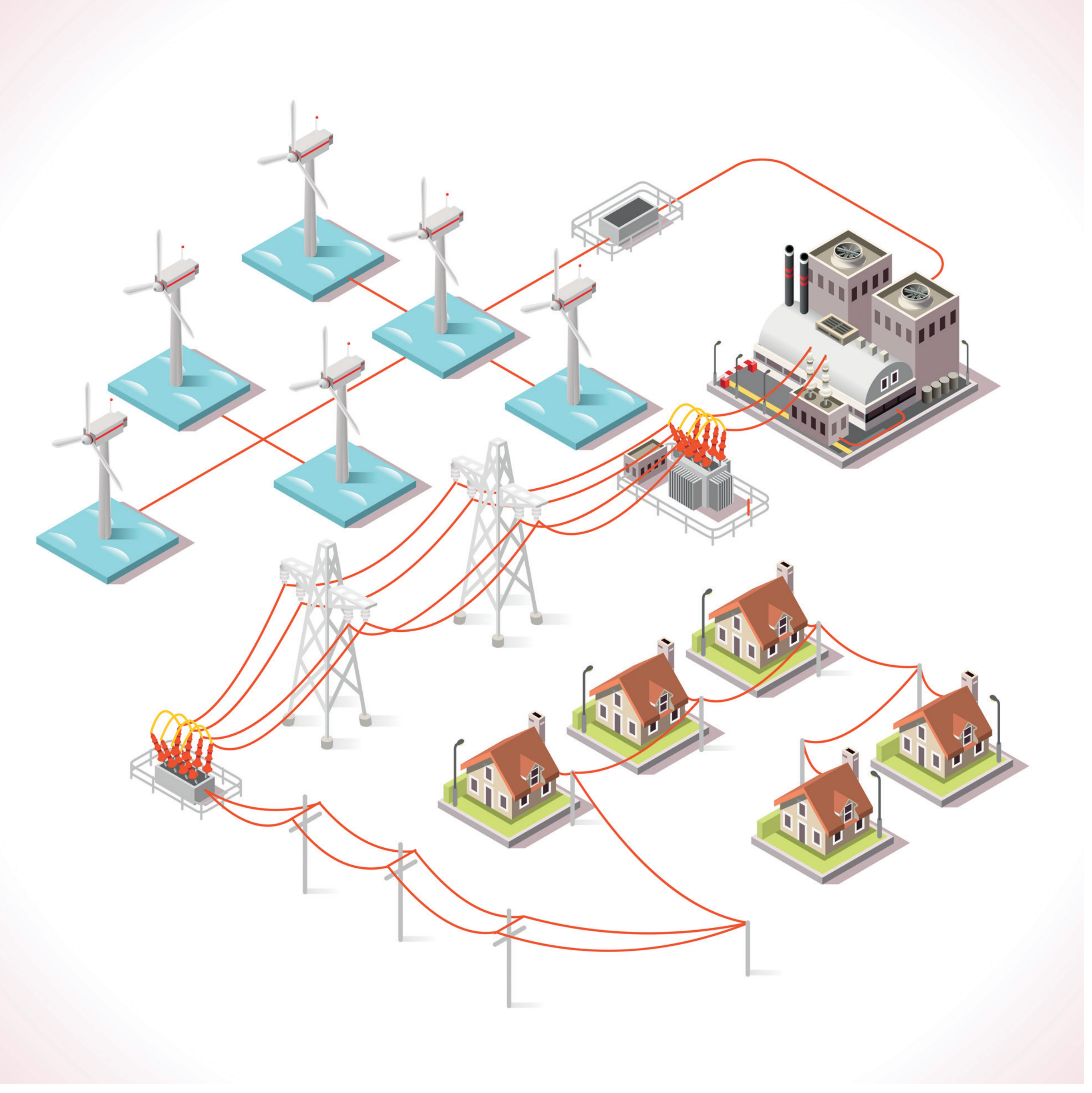


Modern Wind Turbine Photograph

LESSON 3 RESOURCE B

Wind Farm Photograph

Wind Farm Diagram



LESSON 10 RESOURCE A

Energy Transformation Station Setup Instructions

Follow these instructions to set up the Energy Transformation Stations before the lesson.

Note that Stations 1a and 1b work best on a sunny day either outside or by a sunny window. Otherwise, use a flashlight as a light source.

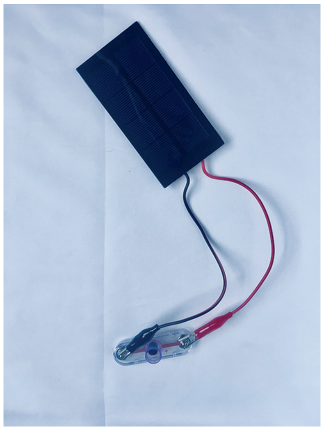
The materials listed for each station should be doubled so two of each can be set up.

Station 1a: Solar Cell

Materials (per station): Snap Circuits® Green kit (solar cell, horn, black jumper wire, red jumper wire), black construction paper (if using sunlight as light source) OR flashlight, Solar Cell Procedure Sheet (see Lesson 10 Resource B)

Preparation:

1. Place all materials at the station.
2. Connect the solar cell and horn as shown below.



3. Confirm that the device functions correctly by exposing the solar cell to the selected light source and removing the light source (either by turning off the flashlight or blocking the sunlight with construction paper). The device should make a sound when the solar cell is exposed to light.

Station 1b: Radiometer

Materials (per station): radiometer, black construction paper (if using sunlight as light source) OR flashlight, Radiometer Procedure Sheet (see Lesson 10 Resource B)

Preparation:

1. Place all materials at the station.
2. Confirm that the available sunlight is sufficient to move the radiometer. Place the radiometer in the sunlight and watch for movement. If there is not enough sunlight, use a flashlight instead.

Station 2a: Balloon

Materials (per station): high-quality balloon (1 per student), Balloon Procedure Sheet (see Lesson 10 Resource B)

Preparation: Place all materials at the station. No additional setup is required.

Station 2b: Sound Cup

Materials (per station): 9-ounce clear plastic cup, piece of plastic wrap (large enough to fit over cup), rubber band, 1 tbsp of dry rice, speaker and audio source (if available), Sound Cup Procedure Sheet (see Lesson 10 Resource B)

Preparation:

1. Place all materials at the station.
2. If using a speaker, cue the audio source and set the volume to its lowest setting. Otherwise, students can talk to the cup at different volumes.
3. Students work together to create the device for the station as shown below. Note that students may need help securing the plastic wrap around the cup.

Station 3a: Ice Melt

Materials (per station): 5 cups of ice, 3 9-ounce clear plastic cups, large bowl, heat lamp, Ice Melt Procedure Sheet (see Lesson 10 Resource B)

Preparation:

1. Place all materials at the station.
2. Add equal amounts of ice to each cup (about one-quarter of the cup), and fill the bowl with ice. Place one cup 6 to 8 inches away from the heat lamp. Place the second cup on the table, away from the heat lamp. Place the third cup in the bowl of ice, away from the heat lamp. Keep the lamp off until the beginning of the Learn section.



Station 3b: Air Temperature

Materials (per station): 2 9-ounce clear plastic cups, heat lamp, 2 small binder clips, 2 mercury-free classroom thermometers, Air Temperature Procedure Sheet (see Lesson 10 Resource B)

Preparation:

1. Place all materials at the station.
2. Secure one thermometer in each cup with a small clip as shown below. Place one cup 6 to 8 inches away from the heat lamp. Place the second cup on the table, away from the heat lamp.


Energy Transformation Station Procedure Sheets

These sheets provide students with directions for each station. Cut out and display the relevant Procedure Sheet at each station.

Station 1a: Solar Cell (flashlight)

1. Add light by turning on the flashlight and pointing it at the solar cell. Observe and record what happens.
2. Remove light by turning off the flashlight. Observe and record what happens.
3. Explore: How can you change the sound?

Station 1b: Radiometer (flashlight)

1. Add light by turning on the flashlight and pointing it at the fins of the radiometer. Observe and record what happens.
2. Explore: How can you change the speed or direction of the fins?

Station 1a: Solar Cell (sunlight)

1. Add light by removing the black piece of paper covering the solar cell. Observe and record what happens.
2. Remove light by covering the solar cell with the black piece of paper. Observe and record what happens.
3. Explore: How can you change the sound?

Station 1b: Radiometer (sunlight)

1. Add light by removing the black piece of paper covering the radiometer. Observe and record what happens.
2. Remove light by covering the radiometer with the black piece of paper. Observe and record what happens.
3. Explore: How can you change the speed or direction of the fins?

Station 2a: Balloon

1. Without blowing up the balloon, try to make a sound through the opening of the balloon. Observe and record what happens.
2. Blow air into the balloon and pinch the opening closed.
3. Slowly let the air out of the balloon while holding the opening of the balloon. Observe and record what happens.
4. Explore: How can you change the sound you hear?

Station 2b: Sound Cup (with speaker)

1. Gently stretch the piece of plastic wrap over the top of the cup. Secure the plastic wrap to the cup with a rubber band.
2. Place about 5 to 10 grains of rice on the plastic wrap.
3. Place the sound cup near the speaker.
4. Turn on the speaker and slowly increase the volume. Observe and record what happens.
5. Explore: How can you change what the rice does?

Station 2b: Sound Cup (without speaker)

1. Gently stretch the piece of plastic wrap over the top of the cup. Secure the plastic wrap to the cup with a rubber band.
2. Place about 5 to 10 grains of rice on the plastic wrap.
3. Talk or make noises with your mouth next to the cup. Observe and record what happens.
4. Speak or make noise more loudly. Observe and record what happens.
5. Explore: How can you change what the rice does?

Station 3a: Ice Melt

1. Observe the ice in the cups.
2. Compare your observations of the ice in each cup with your observations of the ice from the beginning of class.

Station 3b: Air Temperature

1. Observe both cups.
2. Record the temperature of the air in each cup.
3. Compare the temperatures.

LESSON 10 RESOURCE C

Extension: Energy Transformation Station Setup Instructions

Follow these instructions to set up the Energy Transformation Stations extensions before the lesson.

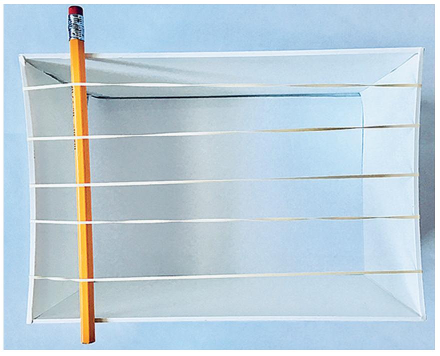
The materials listed for Stations 2c, 2d, and 2e should be doubled so two of each can be set up. Station 3c is teacher guided, so only one station should be set up.

Station 2c: Rubber Band Box (sound)

Materials (per station): shoebox, large rubber bands of varying widths (4 or more), pencil, Rubber Band Box Procedure Sheet (see Lesson 10 Resource E)

Preparation:

1. Place all materials at the station.
2. Build the rubber band box. First, remove the lid of the shoebox. Next, stretch the rubber bands around the box, spacing them evenly. Finally, weave the pencil through the rubber bands at one end of the box.



Station 2d: Kazoo (sound)

Materials (per station): kazoo (1 per student), alcohol pads, Kazoo Procedure Sheet (see Lesson 10 Resource E)

Preparation:

1. Place all materials at the station.
2. No additional setup is required. Sanitize the kazoos with alcohol pads before each new group moves to the station.

Station 2e: Tuning Fork (sound)

Materials (per station): tuning fork, Tuning Fork Procedure Sheet (see Lesson 10 Resource E)

Preparation:

1. Place all materials at the station.
2. No additional setup is required.

Station 3c: Solar Oven (heat)

Materials: cardboard pizza box (per group), box cutter or scissors, aluminum foil, clear tape, plastic wrap (or a heavy-duty resealable freezer bag), black construction paper, newspapers, ruler or wooden spoon, thermometer

Preparation:

1. Place all materials at the station. Note: This teacher-guided activity does not require a procedure sheet.
2. Follow these directions for making the solar oven (Home Science Tools, n.d.): http://phdsci.link/1161. This activity must be done on a clear, sunny day.

Extension: Energy Transformation Station Guidance

Station 2c: Rubber Band Box (sound)

The Rubber Band Box Procedure Sheet directs students to pluck stretched rubber bands and make observations about the resulting movements and sounds.

Sample student observations:

- *The rubber bands don't move unless we pluck them.*
- *When we pluck the rubber bands, they move back and forth really fast and we hear a sound.*
- *The skinnier rubber bands move faster and make a higher-pitched sound than the thicker rubber bands.*

Station 2d: Kazoo (sound)

The Kazoo Procedure Sheet directs students to blow into a kazoo with different bursts of air (soft, medium, and hard) to make sounds.

Sample student observations:

- *The kazoo is louder when we blow harder.*
- *The kazoo isn't as loud when we blow softer.*
- *Blowing into the kazoo tickles our lips.*

Station 2e: Tuning Fork (sound)

The Tuning Fork Procedure Sheet directs students to strike a tuning fork on the table with different forces (light, medium, hard).

Sample student observations:

- *The sound is louder or softer based on how hard or soft we hit the tuning fork on the table.*
- *The harder we hit the tuning fork on the table, the louder the sound it makes is.*
- *We also notice that the tuning fork shakes back and forth more when we hit it harder on the table.*

Station 3c: Solar Oven (heat)

This teacher-guided activity can be conducted in small groups or as a class.

Sample student observations:

- *Sunlight makes the food get hot enough to cook.*
- *We need to use a shiny surface for the solar oven to get hot enough.*

Extension: Energy Transformation Station Procedure Sheets

These sheets provide students with directions for each extension station. Cut out and display the relevant Procedure Sheet at each station.

Station 2c: Rubber Band Box

1. Pluck the rubber bands.
2. Observe and record what happens.
3. Explore: How can you change the sound made with the rubber band box?

Station 2d: Kazoo

1. Blow air into the kazoo with different types of breath (soft, medium, and hard).
2. Observe and record what happens.
3. Explore: How can you change the sound made with the kazoo?

Station 2e: Tuning Fork

1. Tap the tuning fork once on the table (light, medium, or hard). Observe and record what happens.
2. Tap the tuning fork once again but with a different force (light, medium, or hard). Observe and record what happens.
3. Explore: How can you change the sound made with the tuning fork?

Name: ______________________ Date: ____________

LESSON 10 RESOURCE F

Extension: Energy Transformation Observations

As you visit each station, record observations about the energy transformations.

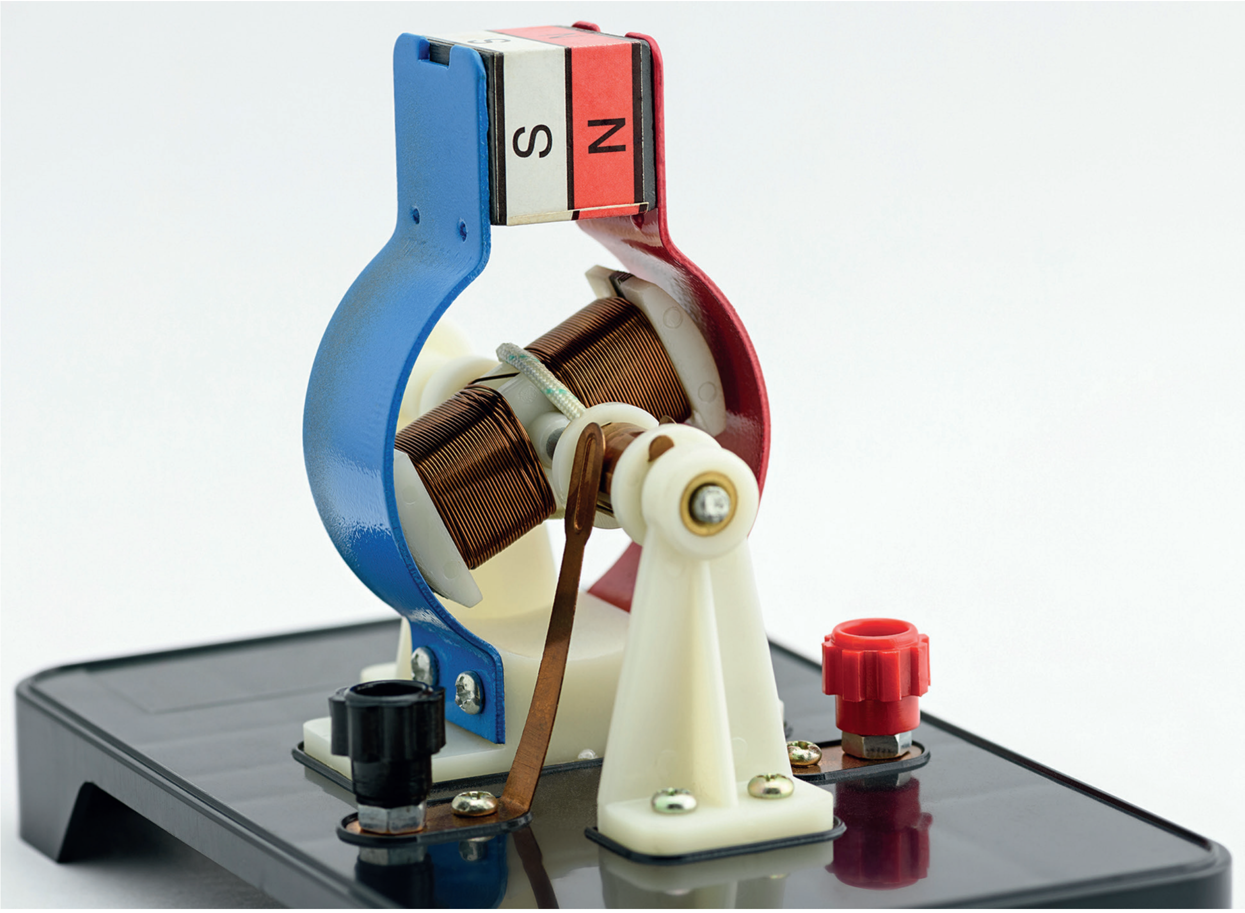
Station 2c: Rubber Band Box
Observations

Station 2d: Kazoo
Observations

Station 2e: Tuning Fork
Observations

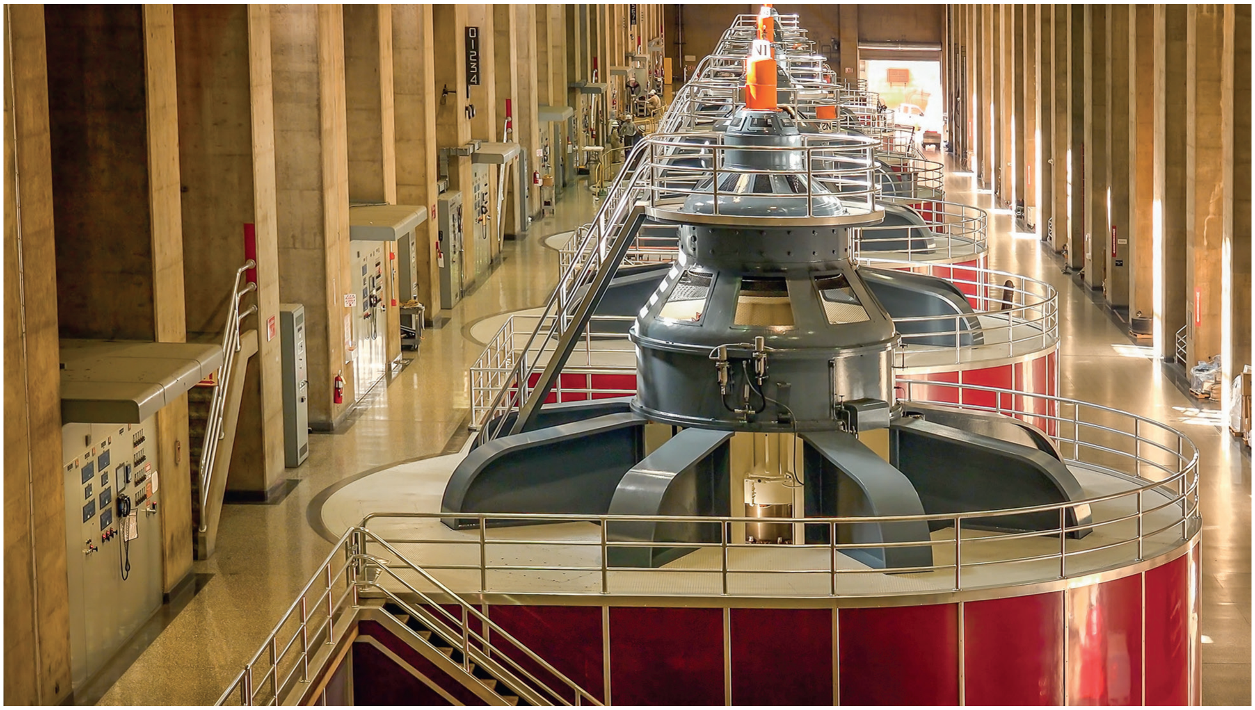
Station 3c: Solar Oven
Observations

Generator Photograph



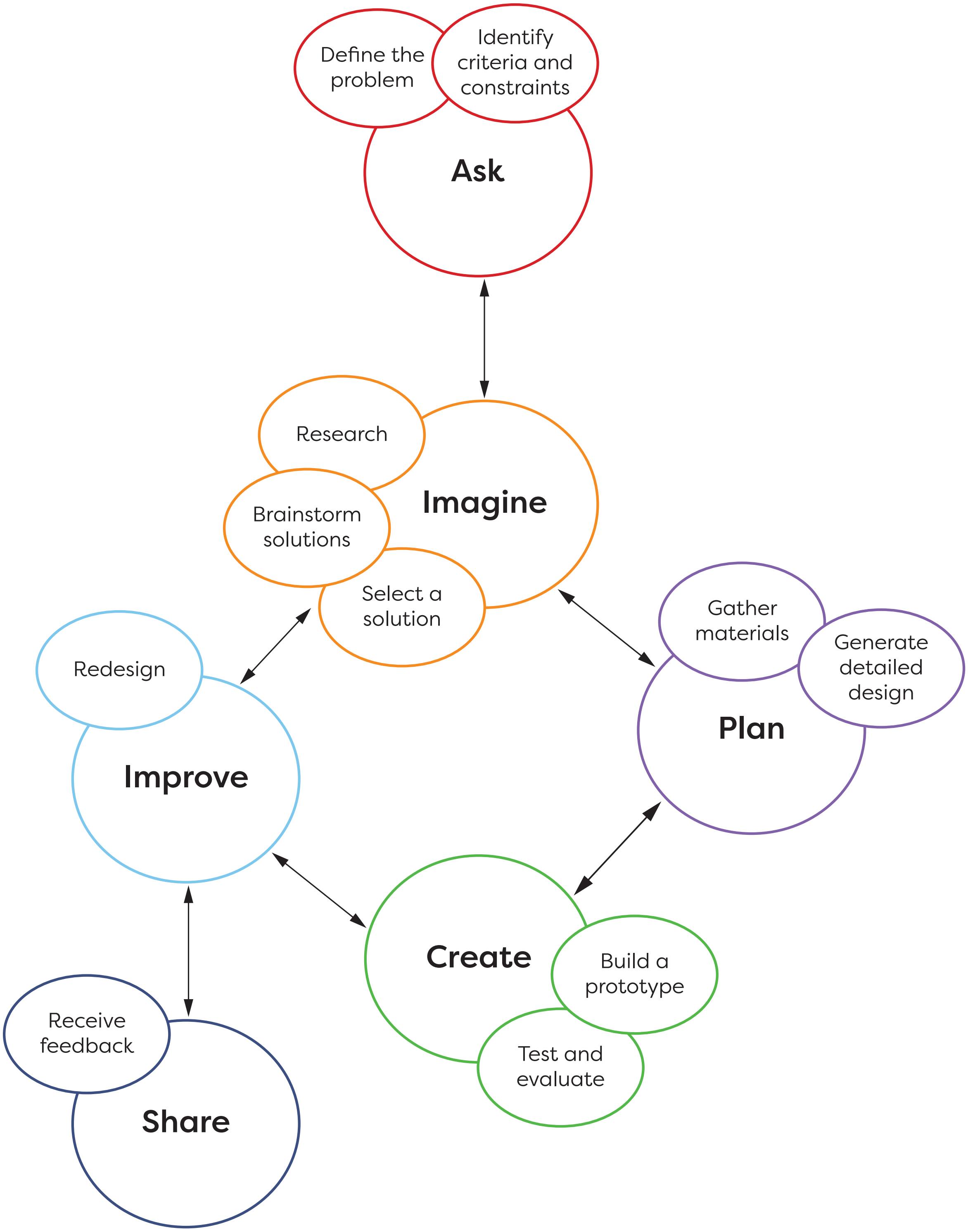
LESSON 15 RESOURCE

Hoover Dam Turbines Photograph



LESSON 17 RESOURCE

Engineering Design Process



Content Standards

Differentiate among forms of energy, including mechanical, sound, electrical, light, and thermal.

Differentiate between conductors and insulators of thermal and electrical energy.

Demonstrate that electricity travels in a closed path, creating an electrical circuit.

Design a descriptive investigation to explore the effect of force on an object such as a push or a pull, gravity, friction, or magnetism.

Appendix B

Module Storyline

Anchor Phenomenon: Windmills at Work

Essential Question: How do windmills change wind to light?

Conceptual Overview

Energy can be neither created nor destroyed, but people harness energy by transferring it to the desired place or transforming it into a form people can use.

1. Energy is why things happen.
2. People can observe phenomena that indicate the presence of energy. It can be useful to classify those indicators into categories such as sound, light, heat, electricity, and the motion of objects.
3. Energy can transfer between objects through collisions and from place to place through electric currents, sound, heat, and light.
4. Energy transformation occurs when one phenomenon indicating the presence of energy changes into any other energy phenomenon.

Focus Content Standards

4.6A	Differentiate among forms of energy, including mechanical, sound, electrical, light, and thermal.
4.6B	Differentiate between conductors and insulators of thermal and electrical energy.
4.6C	Demonstrate that electricity travels in a closed path, creating an electrical circuit.

Concept 1: Energy and Its Classifications (Lessons 1–5)

Focus Question: What is energy?

Lessons 1–3

Phenomenon Question: How do windmills harness the wind?

Phenomenon: Windmills at Work (anchor phenomenon)

Lesson Set Objective: Students observe the transfer of energy, create a model to explain how windmills work, and develop a driving question board.

Knowledge Statement: Everything that happens in a system is caused by energy.

Wonder:* First, we view historic paintings of windmills, a video of the inside of a working windmill, and photographs of present-day windmills. We ask questions about the windmills' structure and function. The answers to these questions allow us to start finding out how these structures have helped us in the real world for many years, such as allowing people to grind wheat into flour. As technology advances, windmill designs and functions have also changed.

We notice different characteristics about the windmills:

- *Windmills are really big. That one is taller than the trees.*
- *They look like a house with a fan on top.*
- *The windmill fans have holes in them. They also have some kind of stick that connects to the house.*
- *The windmills in the paintings look very similar.*

We wonder about ideas such as these:

- *What's inside the house part of the windmill?*
- *What do people use windmills for? How do they work?*
- *How does the windmill spin if the fans have holes in them?*
- *Are these paintings of the same windmill? Do all windmills look like this?*
- *Why don't these windmills look like the tall, skinny ones that I have seen before?*

Organize: We work in small groups to design our own simple paper windmill. We collaborate with other groups to determine the best design for our windmill models. We figure out that how fast the blades spin depends on the amount of wind.

Next, our teacher reads to us a part of the book *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer 2010). We participate in a group discussion about the hardships of living in the less-developed country of Malawi, Africa, where the story takes place. Then we discuss what steps William, the main character in the story, takes to harness the wind and save his village from drought, connecting our learning to a real-world problem.

After this discussion, we problem solve how to make our own present-day windmills by using circuit kits to light up a light-emitting diode (LED) with wind.

* The purple headings indicate the relevant content stage within the content learning cycle. See the Implementation Guide for more information on the content learning cycle.

Wonder: Next, we continue to work together to answer the question How do windmills harness the wind? We begin by viewing a photograph and diagram of a wind farm side by side.

We notice different characteristics about the two wind farms:

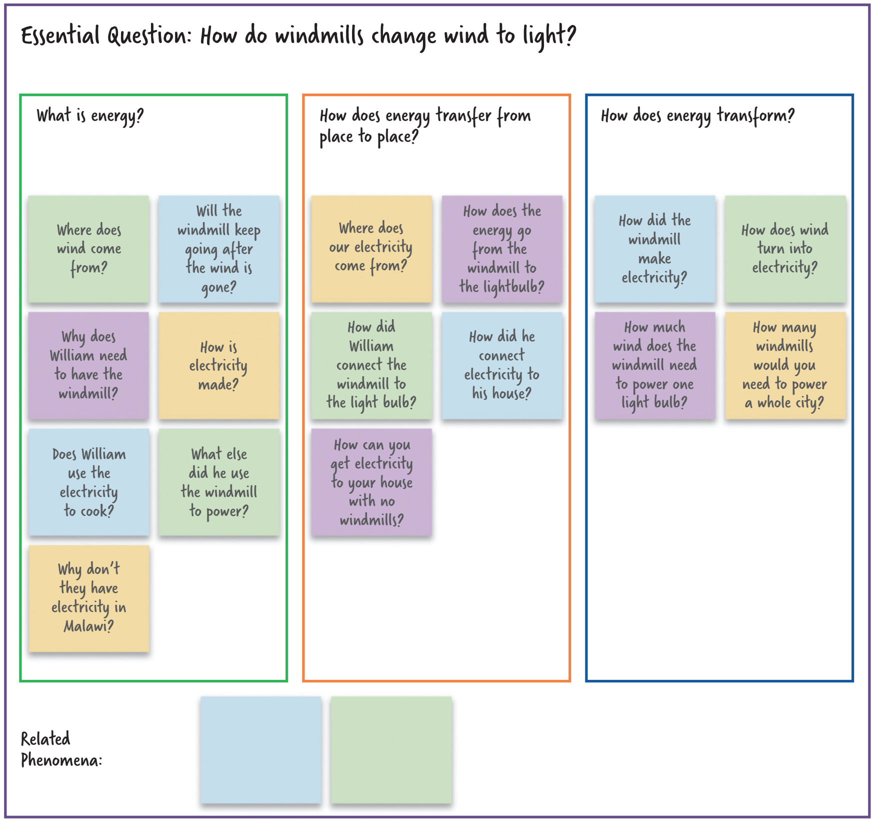
- *The wind turbines are tall and skinny in both. Even the blades are skinny.*
- *Two cords or pipes are coming out of the water. Or maybe they are going in.*
- *The red lines connect the wind farm to houses. They go through other things in the middle.*

We wonder about the two wind farms:

- *In the diagram, does electricity flow through all the wires?*
- *What are those black cords in the photograph?*
- *What do these windmills do? How do they make electricity?*

Organize: Next, we determine that the electricity going through the wires is energy. Then, we work together as a class to develop an anchor model of how a windmill works by using evidence from our paper windmill and our circuit kit. We start to understand what energy is through these models.

We then construct a driving question board with the questions that we have regarding the changing energy in the windmill model. We plan to answer these questions: What is energy? How does energy transfer from place to place? How does energy transform?



Next Steps: Through class discussion, we determine that the best place to start answering the Essential Question is with the first question: What is energy?

<table>
<tr><th colspan="2">Lessons 4–5</th></tr>
<tr><td> Phenomenon Question: How do we know energy is present? Phenomenon: Energy Indicators Lesson Set Objective: Students observe patterns to identify indicators for the presence of energy. They use these indicators as evidence to explain when energy is present. Knowledge Statement: Light, sound, temperature change, and motion indicate the presence of energy in a system. </td>
<td> Reveal: We visit six different stations and identify how energy is present at each through patterns we observe. We classify these indicators of the presence of energy into categories: light, moving objects, temperature change, sound, and things that make something happen (e.g., electricity, batteries). Distill: We then record these categories on an anchor chart along with our class definition of energy. We post the anchor chart for the length of the module so we can make changes to it as we discover more information.
<table><tr><th>Energy</th></tr><tr><td>Energy is why things happen.</td></tr><tr><td>Energy is present when we observe something happening (moving objects, light, temperature change, sound) or when something helps make something happen (electricity, batteries).</td></tr></table>
Know: We complete a Conceptual Checkpoint task describing what our classroom would be like without energy. While reflecting on our experiences in the Energy Stations, we find a pattern: Objects that move faster seem to have more energy. Next Steps: We decide that we want to find the answer to this question: What is the relationship between energy and speed? </td></tr>
<tr><th colspan="2">Concept 2: Energy Transfer (Lessons 6–9)
Focus Question: How does energy transfer from place to place?</th></tr>
<tr><th colspan="2">Lessons 6–7</th></tr>
<tr><td> Phenomenon Question: What is the relationship between energy and speed? Phenomenon: Effect of Energy on Speed Lesson Set Objective: Students test a prediction by planning a fair test investigation to explore the cause and effect relationship between energy and speed. Knowledge Statement: The speed of an object is related to the energy of the object. </td>
<td> Organize: We work together as a class to develop a working explanation that answers the question What is the relationship between energy and speed? Reveal: As a class, we decide on three different investigations to determine whether our explanation is correct. We use evidence from our investigations to help show the cause and effect relationship between energy and speed. However, we need to gather more evidence, so we design a fair test. We work as a class to design a fair, reliable, and precise investigation to gather evidence about the relationship between energy and speed. We make sure to think about speed, distance, and time when we design and conduct our investigations. We practice collecting accurate data. We then analyze our data and look for patterns. Next Steps: We wonder how we might determine whether ball bearings moving with greater speed actually have more energy. We agree that if the bearing has more energy, it can push an object farther, so we decide to explore the question What happens to energy when objects collide? </td></tr>
</table>

Lessons 8–9

Phenomenon Question: What happens to energy when objects collide?

Phenomenon: Energy Changes during a Collision

Lesson Set Objective: Students collect and graph data to identify patterns in the transfer of energy between colliding objects.

Knowledge Statement: Energy in a system can transfer between objects through collisions, causing changes in their motion.

Reveal: We conduct a fair test investigation to see what happens when one ball bearing crashes into an object, an open rectangular prism that we call a catch. After we analyze our data, we make a bar graph to help us look for patterns in the data.

Distill: To help us understand how energy is transferred, we develop a class model of what happens before, during, and after the collision, being careful to show where all the energy is in the system and what phenomena we observe.

We use our models and evidence from our investigations to explain that the more energy given to an object, the greater the speed of that object, and the greater the speed of the object, the more energy of motion that object can transfer to another object.

Next, we add the evidence from our models to the driving question board to answer the question How does energy transfer from place to place?

We discover ideas such as the following:

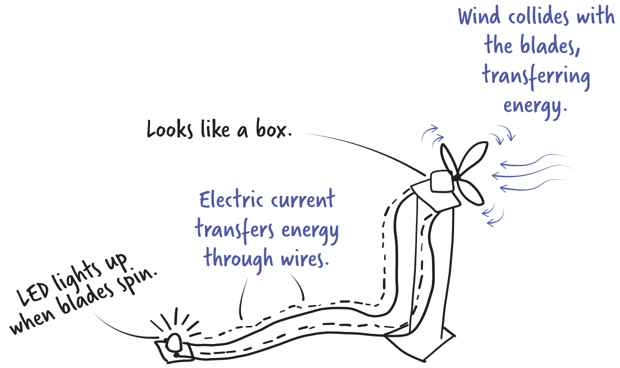
- *We put energy into the system by lifting the ball bearing.*
- *When more energy is transferred, the object moves with more speed.*
- *Sound means there is energy present.*
- *Temperature change means there is energy present.*

We add our new knowledge to the anchor chart and update our anchor model with our new discoveries, which include the following:

- *Wind collides with the windmill blades, pushes the blades, and transfers energy.*
- *Energy is carried through the wires of the windmill by an electric current.*

Energy
Energy is why things happen.
Energy is present when we observe something happening (moving objects, light, temperature change, sound) or when something helps make something happen (electricity, batteries).
Energy can transfer between objects through collisions, causing changes in their motion. • Transferring more energy to an object can make it move faster. • Faster-moving objects have more energy to transfer to other objects. Energy can also transfer from place to place through electric currents.

How a Windmill Harnesses the Wind



In the windmill system, wind collides with the blades, which transfers energy to something that looks like a box. An electric current transfers energy through the wires and turns on the light. When the wind blows harder, more energy is transferred to the blades.

Know: In a Conceptual Checkpoint, we apply our learning to model a collision between a golf club and ball.

Next Steps: Curious about how motion becomes sound and light and how the energy from the wind turns into light, we decide we need to answer the question What do we observe when energy transforms?

Concept 3: Energy Transformation (Lessons 10–16)

Focus Question: How does energy transform?

Lessons 10–11

Phenomenon Question: What do we observe when energy transforms?

Phenomenon: Changes in Energy Indicators

Lesson Set Objective: Students develop a model to show how energy transforms. They then identify patterns and relationships in their observations to understand that energy transferred by light, sound, and heat may transform to produce new energy phenomena.

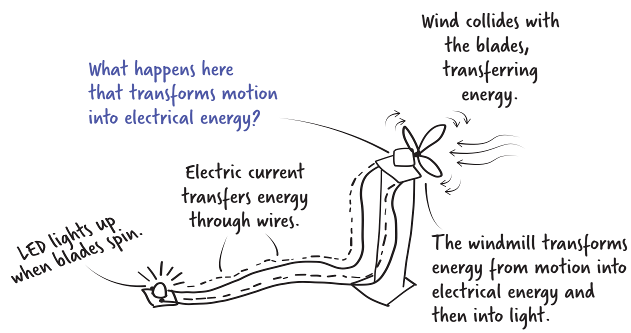
Knowledge Statement: Energy transforms by changing from one form to another.

Reveal: We work in small groups and visit six different stations that focus on the following energy indicators: light, sound, and heat. After visiting the stations, we develop models of the energy transformations we observe. We observe the pattern that energy transforms from one indicator into another.

Distill: After sharing evidence from these stations, we add to the anchor chart our observation that energy transformation occurs when one energy indicator changes into any other energy indicator(s). We also add more detail to our anchor model: The windmill transforms motion into electricity and then into light.

Energy
Energy is why things happen.
Energy is present when we observe something happening (moving objects, light, temperature change, sound) or when something helps make something happen (electricity, batteries).
Energy can transfer between objects through collisions, causing changes in their motion. • Transferring more energy to an object can make it move faster. • Faster-moving objects have more energy to transfer to other objects. Energy can also transfer from place to place through electric currents, sound, heat, and light.
Energy transformation occurs when we observe one energy indicator changing into any other energy indicator(s).

How a Windmill Harnesses the Wind



In the windmill system, wind collides with the blades, which transfers energy to something that somehow transforms mechanical energy into electricity. An electric current transfers energy through the wires and turns on the light. When the wind blows harder, more energy is transferred to the blades. The windmill system transforms mechanical energy into electrical energy and then to light.

Next Steps: Looking at our anchor model of the windmill, we want to understand the answer to the question How does the windmill generate electricity?

Lessons 12–14

Phenomenon Question: How do windmills generate electricity?

Phenomenon: Generating Electricity

Lesson Set Objective: Student groups build a simple generator and make observations to explain how it plays a role in both energy transfer between the windmill blades and the light and transformation of mechanical energy to electrical energy.

Knowledge Statement: A generator can be used to transform mechanical energy into electrical energy.

Organize: Through discussion we determine that the box behind the windmill must transform mechanical energy into electrical energy. In pictures of generators, we observe that they all have wires and magnets.

Reveal: We work in groups to build our own generators with provided materials. We manipulate the materials by spinning the nail at different rates and discover that if we spin the nail slowly, the LED does not light, but if we increase the speed, the LED lights up. The faster we spin the nail, the more mechanical energy there is, and the mechanical energy then transforms into electrical energy.

We make observations such as these:

- *Energy is transferred from the spinning magnets to the wires.*
- *Electrical energy is transferred through the wires to the LED.*
- *Mechanical energy is transformed into electrical energy.*
- *Electrical energy is transformed into light.*

Distill: After debriefing our observations of the generators, we describe the energy transfers and transformations that occurred.

Next Steps: We agree that we are ready to answer our Essential Question: How do windmills change wind to light?

Lessons 15–16

Phenomenon Question: How do windmills change wind to light? (Essential Question)

Phenomenon: Windmills at Work

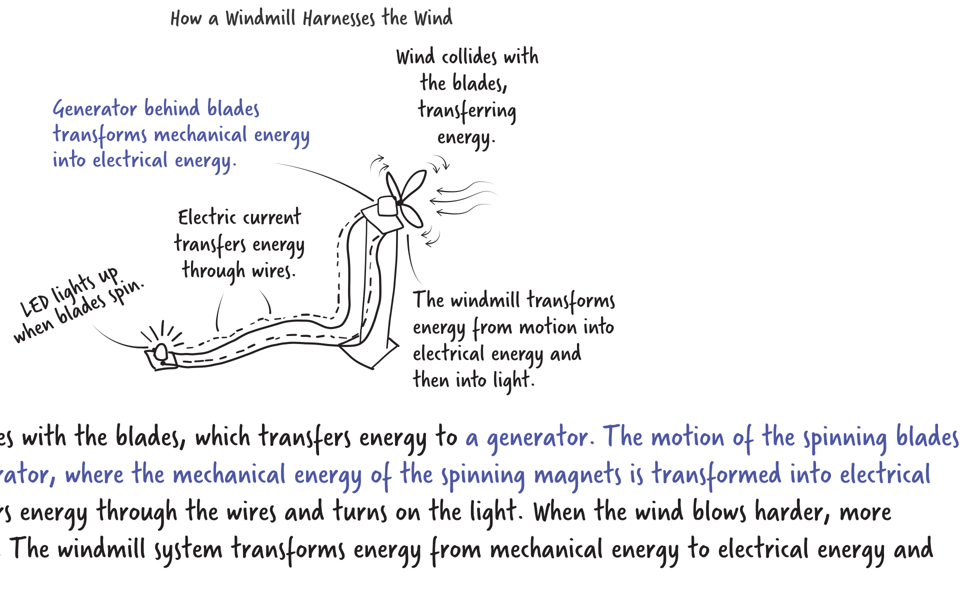
Lesson Set Objective: Students revise the class anchor model and apply their new understanding of energy to explain how energy is transferred and transformed and answer the Essential Question.

Knowledge Statement: Everything that happens can be explained by the transfer and transformation of energy.

Distill: We realize that we have learned a lot about energy during the module, and we list what we have learned in a key concepts checklist. Our checklist includes the following concepts:

- Energy transformations
- Energy transfers
- Relationship between energy and speed
- Different indicators of energy

Through class discussion, we also update our original anchor model to include all the items on our key concepts checklist. As we add new items to our model, we justify our reasoning with evidence from the activities we completed.



Next, we revisit *The Boy who Harnessed the Wind* (Kamkwamba and Mealer 2010) and discuss how the boy, William, solved a problem by building a windmill.

Know: In a Conceptual Checkpoint, we develop an explanation for how a windmill could power a water pump, applying our knowledge from the key concepts checklist.

Next Steps: Next we agree we can engineer our own devices to solve a problem and answer the question How can we apply our knowledge of energy to solve a problem?

Application of Concepts (Lessons 17–26): Engineering Challenge, Socratic Seminar, End-of-Module Assessment *Essential Question: How do windmills change wind to light?*	
Lessons 17–23 (Engineering Challenge)	
Phenomenon Question: How can we apply our knowledge of energy to solve a problem? **Phenomenon:** Apply the engineering design process to construct and refine a device that transforms energy. **Lesson Set Objective:** After reviewing the engineering design process, students identify an available energy source, a desired application of energy, and the materials available to propose a solution. Students then apply what they have learned about energy transfer and transformations to design a device that transforms energy from an available form into the desired form. **Knowledge Statement:** The engineering design process can be used to create a device to transfer energy and transform it from an available form into the desired form.	First, we talk more about William Kamkwamba. As we listen to his story again, we record examples of the engineering design process we talked about when we learned about the Wright brothers. We place our sticky notes on the Engineering Design Process chart. As we discuss our ideas, we realize the engineering design process is more like a web, and it is not necessary to follow the steps in order. **Know:** Next, we are presented with a challenge: We live in an area that has flooded and must design a device to produce light so we can gather supplies. As we develop a plan in our groups, we must think about the criteria, the constraints, and the materials available to us. We then create a model of our plan and receive feedback from our classmates, so we can improve our designs. After a few days of building our models, we share them with the rest of the class and give our classmates relevant feedback. We use the feedback we receive and improve our models to make them more effective. After we have a chance to improve our designs, we present our work to the class and receive feedback from our classmates. *Next Steps:* We are ready to demonstrate what we've learned in an End-of-Module Assessment.

Lessons 24–26 (Socratic Seminar, End-of-Module Assessment, End-of-Module Assessment Debrief)	
Phenomenon Question: How do windmills change wind to light? (Essential Question) **Phenomenon:** Windmills at Work **Lesson Set Objective:** Students apply their knowledge of patterns and systems to construct explanations about energy, how it transfers from place to place, and how it transforms. **Knowledge Statement:** In a system, specific indicators of energy can be generated through energy transfers and transformations.	**Distill:** As a class we participate in a Socratic Seminar and discuss our Essential Question: How do windmills change wind to light? We use the driving question board, the anchor chart, and the anchor model to help us answer this question. **Know:** We show our understanding of energy in the End-of-Module Assessment and then reflect on our learning about energy and the assessment. *Next Steps:* We share our thoughts about how energy plays a role in our lives and in nature.

Appendix C

Module Glossary

These are Level 4–appropriate descriptions of the module terminology and are not intended to be complete definitions.

Term	Description	Lesson
Collision	when two objects hit each other; transfers energy	7
Energy	necessary to make something happen	3
Energy transfer	the movement of energy from one part of a system to another	8
Energy transformation	when one form of energy changes into another; produces changes in indicators of energy	9
Generator	a device that transforms mechanical energy into electrical energy	12
Indicators of energy	show the presence of energy; can be classified as sound, light, temperature change, and motion	5
Speed	the distance an object moves in a certain amount of time	7
System	a group of objects that interact	8

Appendix D

Content-Specific Words, General Academic Words, and Spanish Cognates

	Word(s)	Spanish Cognate
Module Key Terms (Tier Two or Three)	Collision	None
	Energy	Energía
	Energy transfer	Transferencia de energía
	Energy transformation	Transformación de energía
	Generator	Generador
	Indicators of energy	Indicadores de energía
	Speed	None
	System	Sistema

	Word(s)	Spanish Cognate
Content-Specific Words (Tier Three)	Distance	Distancia
	Electricity	Electricidad
	Heat	None
	Light	None
	Sound	Sonido
	Time	None
	Wind	None
	Windmill	None
General Academic Words (Tier Two)	Analyze	Analizar
	Data	Datos
	Fair (adj.)	None
	Generate	Generar
	Harness (v.)	None
	Object (n.)	Objeto
	Precise	Preciso
	Reliable	None
	Transfer	Trasferir
	Transform	Transformar

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