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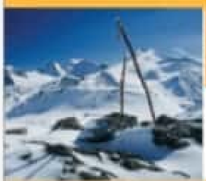
GRADE 6 • VOLUME 1

McGraw Hill Education

CHAPTER **1**

Methods of Science

TheBIGIdea
What processes do scientists use when they do scientific investigations?



1.1 Case Study
- What is the relation between independent variables and dependent variables?
- How is scientific inquiry used in a real-life scientific investigation?

1.2 Saruq Al-Hadid Study
- How is scientific inquiry used in a real-life scientific investigation in modern discovery?

2

PAGE KEELEY SCIENCE PROBES

Desert Descriptions

Deserts are one of the seven major land biomes. Put an next to any of the characteristics that can describe a desert.

- ☐ A. Earth's driest ecosystem
- ☐ B. Can be hot during the day and cold at night
- ☐ C. Can be very cold all the time
- ☐ D. Has soil that holds water
- ☐ E. Has plants that can store water
- ☐ F. Has plants with large leaves
- ☐ G. Can be near an ocean
- ☐ H. Only found in subtropical areas
- ☐ I. Are always sand-covered
- ☐ J. Lizards, bats, birds, and snakes live there.

Explain your thinking in the space below. Describe what makes a desert different from other biomes.

Methods of Science

TheBIGIdea

There are no right or wrong answers to these questions. Write student generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL What are different groups of living things?	*Students may suggest different kinds of animals, plants and animals, or other groups. Use this question to initiate students' thinking about the classification of living things.*
OL How do scientists classify living things into groups?	*Use this question to prompt students to think about the ways living things in a group are similar to each other but different from other groups.*
BL What are some ways the cells in bacteria, plants, and animals differ?	*Use this question to begin a discussion of the differences between eukaryotic and prokaryotic cells and between plant and animal cells.*

PAGE KEELEY SCIENCE PROBES

The Scientific Method

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.

* Sometimes people aren't sure what will happen because they don't know everything that might be having an effect.

* Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments

* Sometimes similar investigations give different results because of unexpected differences in the things being investigated, the methods used, or the circumstances in which the investigation is carried out, and sometimes just because of uncertainties in observations.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1 Case Study

1 The independent variable is the factor a scientist changes to observe how it affects a dependent variable. A dependent variable is the factor a scientist measures or observes during an experiment.

2 Scientific inquiry was used throughout the investigation of the Iceman when hypotheses, predictions, tests, analysis, and conclusions were developed.

Identifying Misconceptio

Scientific Theories

Find Out What Students Think

Students might think that ...

... a scientific theory is just an educated guess that is not backed up by much information. While an everyday theory is generally an educated guess, a scientific theory is an explanation that is based on knowledge gained from many observations and scientific investigations. Before something becomes a scientific theory, it must be fully supported by scientific evidence.

Discussion

Tell students that the theory of plate tectonics states that Earth's crust is divided into plates that move very slowly in relation to each other. **Ask:** How do you think the theory of plate tectonics is different from the theory that your favorite sports team will win their next game if they practice hard? Form small discussion groups. After a set time limit, let students present some of their ideas. Students might correctly state that the theory of plate tectonics is a scientific theory, so it must be supported by many scientific investigations over many years. The theory that their team will win is a guess based on their experience or general observation that practice usually improves performance.

Promote Understanding

Activity Perform this activity to help students understand how evidence is used to construct a scientific theory.

1. Use trusted scientific sources to find a variety of evidence that supports the theory of plate tectonics. Print or copy each piece of evidence and make sure that the source information is on each piece. Include one or two from unreliable sources.
2. Form small student groups. Hand out two or three pieces of information to each group. Make sure that each group has different information. Save some pieces of evidence for the end of the activity.
3. Instruct students to determine whether each piece of information is from a trusted scientific source. Tell them to disregard questionable evidence and summarize the information from their trusted sources.
4. Have a student from each group present their summary. Work as a class to develop a statement that explains all of the information presented. This will be the "theory."
5. Share the "new" evidence that you withheld. Have a student read each piece of information. Have the class determine whether the new information fits with the "theory," or whether it causes them to reexamine and alter the "theory."

The International System of Units

Find Out What Students Think

Students might think that ...

... scientists in different countries use different units of measurement. They might be aware that in the United States we use feet, inches, and miles to make measurements, while people in other countries use meters, centimeters, and kilometers. Since we use different measurements in our everyday lives, students might think this extends to scientists. They might not be aware that an International System of Units (SI) was adopted to make it easier for scientists worldwide to share information.

Discussion

Ask: Why do you think that we measure things in centimeters and meters in the classroom when you probably measure things in inches and feet at home? Form small discussion groups and then have students present their answers and supporting evidence. Students might conclude correctly that scientists measure things using the metric system, while U. S. non-scientists mainly use the standard, or English, system. Some students [illegible] know that the metric system is part of an international system of units.

Promote Understanding

Activity Have students perform this activity to discover how difficult communication would be if scientists worldwide used different measuring systems.

1. Form small student groups. Provide half with metersticks and half with yardsticks.
2. Instruct them to measure each person's height in their group. Record each measurement and whether the student is male or female.
3. Make a blank data table using chart paper or the board. Label a column "*Girls*" and the other "*Boys*." When students finish measuring, have them record their data in the table. Remind students to include the units.
4. **Ask:** Can we find the average heights of boys and girls by adding the numbers in each column and dividing by the total number of entries? **No. Some of the measurements are in inches and some are in centimeters.**
5. **Ask:** What do we need to do to find the averages? **Convert inches to centimeters, or convert centimeters to inches.**
6. **Ask:** How could we have made data analysis easier? **Everyone could have used the same units when measuring.**

PAGE KEELEY SCIENCE PROBES

SECTION
1.1 Case Study

Essential Questions

- How are independent variables and dependent variables related?
- How is scientific inquiry used in a real-life scientific investigation?

Vocabulary

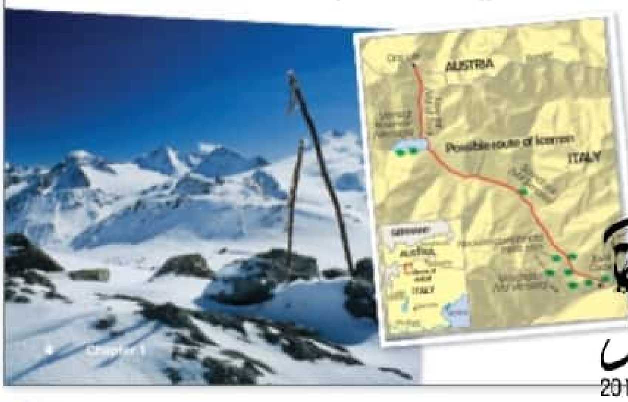
variable
independent variable
dependent variable

The Iceman's Last Journey

The Tyrolean Alps border western Austria, northern Italy, and eastern Switzerland, as shown in **Figure 7**. They are popular with tourists, hikers, mountain climbers, and skiers. In 1991, two hikers discovered the remains of a man, also shown in **Figure 7**, in a melting glacier on the border between Austria and Italy. They thought the man had died in a hiking accident. They reported their discovery to the authorities.

Initially authorities thought the man was a music professor who disappeared in 1938. However, they soon learned that the music professor was buried in a nearby town. Artifacts near the frozen corpse indicated that the man died long before 1938. The artifacts, as shown in **Figure 8**, were unusual. The man, nicknamed the Iceman, was dressed in leggings, a loincloth, and a goatskin jacket. A bearskin cap lay nearby. He wore shoes made of red deerskin with thick bearskin soles. The shoes were stuffed with grass for insulation. In addition, investigators found a copper ax, a partially constructed longbow, a quiver containing 14 arrows, a wooden backpack frame, and a dagger at the site.

Figure 7 Location where Otzi the Ice Man was found, behind the summit of Mt. Similaun in the Otztal Alps on the border of Italy and Austria.



A Controlled Experiment

The identity of the corpse was mystery. Several people hypothe about his identity, but controlled experiments were needed to un the mystery of who the Iceman Scientists and the public wanted know the identity of the man, w he had died, and when he had d

Figure 8 These models show what the Iceman and the artifacts found with him might have looked like.

Identifying Variables and Constants

When scientists design a contro experiment, they have to identify factors that might affect the outc of an experiment. A **variable** is *any factor that can have more than one value.* In controlled experiments, there are two kinds of variables. The **independent variable** is *the factor that you want to test. It is changed by the investigator to observe how it affects a dependent variable.* The **dependent variable** is *the factor you observe or measure during an experiment.* When the independent variable is changed, it causes the dependent variable to change.

A controlled experiment has two groups—an experimental group and a control group. The experimental group is used to study how a change in the independent variable changes the dependent variable. The control group contains the same factors as the experimental group, but the independent variable is not changed. Without a control, it is difficult to know if your experimental observations result from the variable you are testing or from another factor.

Scientists used inquiry to investigate the mystery of the Iceman. As you read the rest of the story, notice how scientific inquiry was used throughout the investigation. The blue boxes in the margins point out examples of the scientific inquiry process. The notebooks in the margin identify what a scientist might have written in a journal.

Scientific investigations often begin when someone asks a question about something observed in nature.

Observation: A corpse was found buried in ice in the Tyrolean Alps.
Hypothesis: The corpse found in the Tyrolean Alps is the body of a missing music professor because he disappeared in 1938, and had not been found.
Observation: Artifacts near the body suggested that the body was much older than the music professor would have been.
Revised Hypothesis: The corpse found was dead long before 1938 because the artifacts found near him appear to date before the 1930s.
Prediction: If the artifacts belong to the corpse, and date back before 1930, then the corpse is not the music professor.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Synonyms and Antonyms

1. Write the word variable on chart paper or the board.
2. **Ask: What does it mean when someone says the weather is variable?** *It means that the weather changes.*
3. **Ask: What do you think a variable in an experiment would be?** *It would be something in the experiment that changes.*
4. Demonstrate to students how variables are used in an experiment. Place two jars at the front of the classroom. Fill one beaker with 100 mL of water. Fill the other beaker with 100 mL of vinegar. **Ask: What is variable in this part of the experiment?** *the type of liquid used*
5. Find the mass of two identical antacid tablets. Discuss the terms *independent variable* and *dependent variable*.
6. Tell students you are going to investigate how long it takes for the tablets to dissolve in each liquid. Drop a tablet into each container and have students record the time it takes each tablet to completely dissolve. **Ask: What is the dependent variable in this part of the experiment?** *The time it takes the tablets to dissolve varies, and is considered the dependent variable.*

The Iceman's Last Journey

The Iceman, also known as Ötzi or Oetzi, was a rare find. At about 5,300 years old, he is one of the oldest, naturally preserved humans ever discovered. Have students read about this discovery, and the items that were near the Iceman. Then as these scaffolded questions.

Guiding Questions

AL Why do you think the hikers who discovered the Iceman thought he died from a mountaineering accident?	*The hikers were in a mountainous area, where a mountain climber or other hiker could have slipped, fallen, and died. It was likely that the Iceman would have been a victim of an accident.*
OL What evidence led inspectors to believe that the Iceman was more than 100 years old?	*Artifacts near the Iceman were unusual and appeared to be from a more ancient time in human history.*
BL IWhy would it be important to carefully document the positions of ancient artifacts and to disturb them as little as possible as they are being excavated?	*Each artifact and its position can provide clues to investigators that could help them to understand when the artifacts were made and how they got to the place where they were found.*

A Controlled Experiment
Identifying Variables and Constants

To solve the mystery of the Iceman, scientists used observation, hypothesis formation, prediction, hypothesis testing, and other tools of scientific inquiry. In some cases, the scientists used controlled experiments. Have students read the material on this page, to learn about the components of a controlled experiment. Then ask these questions.

Guiding Questions

AL What kind of process did scientists use to solve the mystery of the Iceman?	*Scientists used the process of scientific inquiry to solve the mystery. Scientific inquiry can include observation, forming hypotheses, making predictions, and carrying out controlled experiments.*
OL What are the two types of variables in a controlled experiment, and how do they relate to each other?	*The two types of variables are independent and dependent variables. An independent variable is a factor that you want to test. A dependent variable is the factor that is measured during the experiment that might be affected by the independent variable.*
BL An investigator tests the effect of temperature on the rate that a body decays. What are the independent and dependent variables in the experiment?	*Temperature is the independent variable and the rate of decay is the dependent variable.*

Teacher Notes

An inference is a logical explanation of observations based on past experiences.

Inference: Based on its construction, the ax is at least 4,000 years old.
Prediction: If the ax is at least 4,000 years old, then the body found near it is also at least 4,000 years old.
Test Results: Radiocarbon dating showed the man to be 5,300 years old.

After many observations, revised hypotheses, and tests, conclusions often can be made.

Conclusion: The Iceman is about 5,300 years old. He was a seasonal visitor to the high mountains. He died in autumn. When snow came the Iceman's body became buried and frozen in the snow, which preserved his body.

An Early Conclusion

Konrad Spindler was a professor of archeology at the University of Innsbruck in Austria when the Iceman was discovered. Spindler estimated that the ax, shown in **Figure 9**, was at least 4,000 years old based on its construction. If the ax was that old, then the Iceman was also at least 4,000 years old. Later, radiocarbon dating showed that the Iceman actually lived about 5,300 years ago.

The Iceman's body was in a mountain glacier 3,210 m above sea level. What was this man doing so high in the snow- and ice-covered mountains? Was he hunting for food, shepherding his animals, or looking for metal ore?

Spindler noted that some of the wood used in the artifacts was from trees that grew at lower elevations. He concluded that the Iceman was probably a seasonal visitor to the high mountains.

Spindler also hypothesized that shortly before the Iceman's death, the Iceman had driven his herds from their summer high mountain pastures to the lowland valleys. However, the Iceman soon returned to the mountains where he died of exposure to the cold, wintry weather.

The Iceman's body was extremely well preserved. Spindler inferred that ice and snow covered the Iceman's body shortly after he died. Spindler concluded that the Iceman died in autumn and was quickly buried and frozen, which preserved his body and all his possessions.

Figure 9 This ax, bow and quiver, and dagger and sheath were found with the Iceman's body.

6 Chapter 1

More Observations and Revised Hypotheses

Scientific investigations often lead to new questions.

When the Iceman's body was discovered, Klaus Oeggl was an assistant professor of botany at the University of Innsbruck. His area of study was plant life during prehistoric times in the Alps. He was invited to join the research team studying the Iceman.

Upon close examination of the Iceman and his belongings, Professor Oeggl found three plant materials–grass from the Iceman's shoe, as shown in **Figure 10**, splinter of wood from his longbow, and a tiny fruit called a sloe berry.

Over the next year, Professor Oeggl examined bits of charcoal wrapped in maple leaves that had been found at the discovery site. Examination of the samples revealed the charcoal was from the wood of eight different types of trees. All but one of the trees grew only at lower elevations than where the Iceman's body was found. Like Spindler, Professor Oeggl suspected that the Iceman had been at a lower elevation shortly before he died. From Oeggl's observations, he formed a hypothesis and made some predictions.

Oeggl realized that he would need more data to support his hypothesis. He requested that he be allowed to examine the contents of the Iceman's digestive tract. If all went well, the study would show what the Iceman had swallowed just hours before his death.

Observations: Plant matter near body to study—grass on shoe, splinter from longbow, sloe berry fruit, charcoal wrapped in maple leaves, wood in charcoal from 8 different trees—7 of 8 types of wood in charcoal grew at lower elevations.
Hypothesis: The Iceman had recently been at lower elevations before he died because the plants identified near him grew only at lower elevations.
Prediction: If the identified plants are found in the digestive tract of the corpse, then the man actually was at lower elevations just before he died.
Question: What did the Iceman eat the day before he died?

Figure 10 Professor Oeggl examined the Iceman's belongings along with the leaves and grass that were stuck to his shoe.

Section 1 Case Study 7

An Early Conclusion

Radiocarbon dating and observations of the Iceman's artifacts indicated that the Iceman was a 5,300 year-old shepherd. Scientists initially hypothesized that the Iceman lived at lower elevations but traveled into the mountains with his herds in summer. For some reason, he had returned to the high mountains in autumn and died of exposure. Have students read about the evidence that led to this early conclusion and then ask these scaffolded questions.

Guiding Questions

AL What are the many things that scientists originally thought the Iceman could have been doing in the high mountains?	*The Iceman could have been hunting for food, prospecting for metal ore, or shepherding his animals.*
OL How did the Iceman's ax and other artifacts help scientists to learn more about the age of the Iceman?	*Scientists could see by the construction of the ax that it was at least 4,000 years old. Radiocarbon dating of the wood on the ax showed that it was 5,300 years old. The wood used in the ax and other artifacts was from trees at a lower elevation, so scientists knew it was not likely that the Iceman lived in the high mountains.*
BL How could the state of the Iceman's body help scientists to understand how he died?	*Any signs of injury would indicate that he might have died from a fight. An absence of injury would indicate that he died from exposure or an illness.*

More Observations and Revised Hypotheses

The research team working on the Iceman mystery included a botanist named Klaus Oeggl. Professor Oeggl learned a lot about the Iceman by studying plant matter near the body. Have students read about Professor Oeggl's findings and then ask these scaffolded questions.

Guiding Questions

AL What does a professor of botany study?	*A professor of botany studies plants.*
OL What types of plant matter at the Iceman site did Professor Oeggl study?	*Professor Oeggl studied grass from the Iceman's shoe, wood from his long bow, sloe berry fruit, and charcoal wrapped in maple leaves.*
BL Why was it important for Professor Oeggl to know about the modern-day plants that grow in the Alps as he worked to solve the Iceman mystery?	*By knowing where current plants grow, the professor could get an idea of the range of the different plants and infer where prehistoric plants grew. This would help him to determine where the Iceman had lived.*

Visual Literacy: More Observations and Revised Hypotheses

Professor Oeggl's observations about the plant material near the Iceman led him to form a hypothesis and prediction. Have students read the material written in the notebook on the page. Then ask these questions.

Ask: What led Professor Oeggl to hypothesize that the Iceman had been at lower elevations before he died? *The plants identified near the Iceman grew at lower elevations.*

Hypothesis: The Iceman had recently been at lower elevations before he died because the plants identified near him grow only at lower elevations.

Prediction: If the identified plants are found in the digestive tract of the corpse, then the man actually was at lower elevations before he died.

Ask: What prediction did Professor Oeggl make? *He predicted that if he could show that plants that grew at lower elevations were in the Iceman's digestive tract, then the Iceman was at lower levels before he died.*

Differentiated Instruction

Middle School Boy Have students work together to write and perform a play about future humans investigating the mysterious Middle School Boy of the early 21st century. Differentiate the act as follows:

AL **Portraying Future Generations** Have AL students act as future humans, discovering the artifacts and hypothesizing to whom they belonged.

BL **Portraying Scientists** Have BL students act as future scientists, using the artifacts to investigate and report conclusions about Middle School Boy.

Teacher Toolbox

Fun Fact

Radiocarbon Dating Radiocarbon dating examines the amount of carbon-14 that is in organic remains, such as wood or bone. Carbon-14 is a radioactive isotope that f when cosmic radiation interacts with carbon in Earth's atmosphere. Plants take up carbon-14 and the nonradioactive carbon-12 when they perform photosynthesis. Each type of carbon is passed to anim when they eat plants. Carbon-12 and carbon-14 are als passed to animals when they eat other animals. Organ stop taking in carbon-12 and carbon-14 when they die. Carbon-12 does not change, but carbon-14 decays at a constant rate within the remains of the organism. Ther scientists can examine the ratio of carbon-14 atoms to carbon-12 atoms in the remains to determine an organi approximate age.

Activity

Examining Plant Parts Professor Oeggl learned about the Iceman by examining plant materials at the discovery s Bring in a variety of parts from different plants, such as leaves, twigs, and bark. Form small student groups and provide magnifying lenses to each group. Instruct each group to write a series of observations about each pla part and to draw sketches. Have students classify the p parts into different groups, based on their physical similarities.

Careers in Science

Archaeologist An archaeologist carefully recovers and studies artifacts from ancient civilizations. Archaeologis help us to understand the history of human culture. Archaeologists generally study anthropology, history, ancient languages, art, art history, and theology. Archaeologists work on digs all around the world, as w in museums, government agencies, and universities.

Experiment to Test Hypothesis

There is more than one way to test a hypothesis. Scientists might gather and evaluate evidence, collect data and record their observations, create a model, or design and perform an experiment. They also might perform a combination of these skills.

Test Plan
- Divide a sample of the Iceman's digestive tract into four sections
- Examine the pieces under microscopes
- Gather data from observations of the pieces and record observations

The research teams provided Professor Oeggl with a tiny sample from the Iceman's digestive tract. He was determined to study it carefully to obtain as much information as possible. Oeggl carefully planned his scientific inquiry. He knew that he had to work quickly to avoid the decomposition of the sample and to reduce the chances of contaminating the samples.

His plan was to divide the material from the digestive tract into four samples. Each sample would undergo several chemical tests. Then, the samples would be examined under an electron microscope to see as many details as possible.

Professor Oeggl began by adding a saline solution to the first sample. This caused it to swell slightly, making it easier to identify particles using the microscope at a relatively low magnification. He saw particles of a wheat grain known as einkorn, which was a common type of wheat grown in the region during prehistoric times. He also found other edible plant material in the sample.

Oeggl noticed that the sample also contained pollen grains in the digestive tract of the Iceman. To see the pollen grains more clearly, he used a chemical that separated unwanted substances from the pollen grains. He washed the sample a few times with alcohol. After each wash, he examined the sample under a microscope at a high magnification. The pollen grains became more visible. Many more microscopic pollen grains could now be seen. Professor Oeggl identified these pollen grains as those from a hop hornbeam tree.

Describe

List the main ideas from this section in the lines below.

Analyzing Results

Professor Oeggl observed that the hop-hornbeam pollen grains had not been digested. Therefore, the Iceman must have swallowed them within hours before his death. But, hop hornbeam trees only grow in lower valleys. Oeggl was confused. How could pollen grains from trees at low elevations be ingested within a few hours of this man dying in high, snow-covered mountains? Perhaps the samples from the Iceman's digestive tract had been contaminated. Oeggl knew he needed to investigate further.

Error is unavoidable in scientific research. Scientists are careful to document procedures and any unanticipated factors or accidents. They also are careful to document possible sources of error in their measurements.

Procedure
- Sterilize laboratory equipment
- Prepare saline slides
- View saline slides under electron microscope. Results: no hop-hornbeam pollen grains
- Add digestive tract sample to one slide
- View this slide under electron microscope. Result: hop-hornbeam pollen grains present

Further Experimentation

Oeggl realized that the most likely source of contamination would be Oeggl's own laboratory. He decided to test whether his lab equipment or saline solution contained hop-hornbeam pollen grains. To do this, he prepared two identical, sterile slides with saline solution. Then, on one slide, he placed a sample from the Iceman's digestive tract. The slide with the sample was the experimental group. The slide without the sample was the control group.

The independent variable, or the variable that Oeggl changed, was the presence of the sample on the slide. The dependent variable, or the variable Oeggl tested, was whether hop-hornbeam pollen grains showed up on the slides. Oeggl examined the slides carefully.

Controlled experiments contain two types of variables.

Dependent Variable: amount of hop-hornbeam pollen grains found on slide
Independent Variable: digestive tract sample on slide

Analyzing Additional Results

The experiment showed that the control group (the slide without the digestive tract [illegible]) contained no hop-hornbeam pollen [illegible] Therefore, the pollen grains had not [illegible] his lab equipment or solutions. [illegible] from the Iceman's digestive tract [illegible] re-examined. All of the samples [illegible] the same hop-hornbeam pollen [illegible] The Iceman had indeed swallowed the [illegible] hornbeam pollen grains.

Without a control group, it is difficult to determine the origin of some observations.

Control Group: sterilized slide
Experimental Group: sterilized slide with digestive tract sample

Experiment to Test Hypothesis

Describe Answer: Answers may vary.

Professor Oeggl performed careful observations on the digestive tract of the Iceman to determine the kinds of plants he had eaten. Have students read the professor's experimental procedure and answer these questions.

Guiding Questions

AL What was the professor looking for when he examined pieces of the Iceman's digestive tract?	*The professor was looking for plant materials that the Iceman had eaten.*
OL What procedures did the professor use when examining the digestive tract?	*He divided the tract into four samples, added saline to the first sample, and examined it using an electron microscope at low magnification. Then he used a chemical to separate unwanted substances in the sample, applied alcohol, and examined it using an electron microscope at a higher magnification.*
BL Why wasn't the examination of the Iceman's digestive tract a controlled experiment?	*Sample answer: The professor did not have a control digestive tract to compare to the Iceman's digestive tract.*

Analyzing Results / Further Experimentation / Analyzing Additional Results

When Professor Oeggl found pollen in the sample of the Iceman's intestines, he performed an experiment to make sure the pollen was not simply contamination from his laboratory. His results showed that the pollen had indeed been swallowed by the Iceman. Have students review Professor Oeggl's procedures and the interpretation of his results. Then ask these questions.

Guiding Questions

AL What kind of contamination did Professor Oeggl think might have happened?	*He thought his sample might have been contaminated by pollen floating around his lab.*
OL What procedures did Professor Oeggl use to test for error?	*He sterilized lab equipment. Then he prepared and viewed a control slide containing just saline to verify that no pollen was present. He also prepared and viewed samples of the Iceman's intestines and found pollen. He re-examined the samples and still found the pollen.*
BL Why was it important for the professor to identify the types of pollen that were found in the Iceman's digestive system?	*By knowing the types of pollen, he could determine where the plants that produced the pollen grew, which could then help determine where the Iceman had traveled before he died.*

Visual Literacy: Analyzing Results

The procedure to find the source of the pollen was a controlled experiment. Have students study the notes on this page related to the procedure and answer these questions.

Without a control group, it is difficult to determine the origin of some observations.

Ask: What were the control and experiment groups in the error analysis? *The control group was the sterilized slide; the experimental group was the sterilized slide with the digestive tract sample.*

Control Group: sterilized slide
Experimental Group: sterilized slide with digestive tract sample

Ask: What was the conclusion of the error analysis? *The laboratory was not contaminated, so the Iceman must have ingested the pollen.*

Procedure:
- Sterilize laboratory equipment.
- Prepare saline slides.
- View saline slides under electron microscope.

Results: no hop-hornbeam pollen grains.
- Add digestive tract sample to one slide.
- View this slide under electron microscope. Result: hop-hornbeam pollen grains present.

Differentiated Instruction

Iceman Comics

Have students create a graphic novel that illustrates the discoveries made by Professor Oeggl as he investigated the mystery of the Iceman. Differentiate the activity as follows.

BL **Summarizing the Story** Have students summarize the information about Professor Oeggl's observations and experiments in their graphic novel.

AL **Making More Stories** Have students use the information they gained about Professor Oeggl and his techniques to create a graphic novel about his further adventures.

BL **Illustrating the Story** Have students use mainly pictures and brief descriptions to illustrate the discoveries of Professor Oeggl.

Teacher Toolbox

Careers in Science

Archaeobotanist An archaeobotanist studies the remains of plants that lived thousands or even millions of years ago. Archaeobotanists study fossilized plants or plant remains such as pollen, that has been trapped in sediment. Archaeobotanists need a good background in chemistry, physics, mathematics, statistics, as well as plant biology and ecology.

Reading Strategy

Linking Specifics and Generalities Have students work in pairs to revisit **Figure 2** in **Lesson 1** of this chapter, which shows the steps of a scientific inquiry. Have students discuss how the investigations related to the Iceman match up with each general scientific inquiry step. Encourage students to record their ideas in their science journal.

Fun Fact

Tracing the Origins of the Chinese Clay Army A life-sized army made entirely of clay, containing 8,000 soldiers, horses, and 200 chariots stands guard over the tomb of the first emperor of China. This army is 2,200 years old, and archaeologists have long wondered where the figures were made. Now scientists are grinding up small pieces of the terracotta soldiers and horses to examine pollen samples embedded in the clay. Scientists have already determined that the horses and soldiers have different types of pollen, so they were likely made at different places. In fact, the mystery of the origin of the horses might be solved. The pollen found in the horse figures matches tree pollen in soils near the tomb. This indicates that the horses were probably made nearby. Scientists have still not determined where the soldiers were made.

OL On Level AL Approaching Level BL Beyond Level

Mapping the Iceman's Journey

An inference is a logical explanation of an observation that is drawn from prior knowledge or experience. Inferences can lead to predictions, hypotheses, or conclusions.

The hop-hornbeam pollen grains were helpful in determining the season the Iceman died. Because the pollen grains were whole, Professor Oeggl inferred that the Iceman swallowed the pollen grains during their blooming season. Therefore, the Iceman must have died between March and June.

After additional investigation, Professor Oeggl was ready to map the Iceman's final trek up the mountain. Because Oeggl knew the rate at which food travels through the digestive system, he inferred that the Iceman had eaten three times in the final day and a half of his life. From the digestive tract samples, Oeggl estimated where the Iceman was located when he ate.

First, the Iceman ingested pollen grains native to higher mountain regions. Then he swallowed hop-hornbeam pollen grains from the lower mountain regions several hours later. Last, the Iceman swallowed other pollen grains from trees of higher mountain areas again. Oeggl proposed the Iceman traveled from the southern region of the Italian Alps to the higher, northern region as shown in **Figure 11** where he died suddenly. He did this all in a period of about 33 hours.

Figure 11 By examining the contents of the Iceman's digestive tract, Professor Oeggl was able to reconstruct the Iceman's last journey.

Conclusion

Scientific investigations may disprove early hypotheses or conclusions. However, new information can cause a hypothesis or conclusion to be revised many times.

Researchers from around the world worked on different pieces of the Iceman mystery and shared their results. Analysis of the Iceman's hair revealed his diet usually contained vegetables and meat. Examining the Iceman's one remaining fingernail, scientists determined that he had been sick three times within the last six months of his life. X-rays revealed an arrowhead under the Iceman's left shoulder. This suggested that he died from that serious injury rather than from exposure.

Finally, scientists concluded that the Iceman traveled from the high alpine region in spring to his native village in the lowland valleys. There, during a conflict, the Iceman sustained a fatal injury. He retreated back to the higher elevations, where he died. Scientists recognize their hypotheses can never be proved, only supported or not supported. However, with advances in technology, scientists are able to more thoroughly investigate mysteries of nature.

My Notes

10 Chapter 1 — Section 1 Case Study 11

Mapping the Iceman's Journey

An inference is a logical explanation based on the information that is available to the scientist. After Professor Oeggl gathered information from the Iceman's digestive system, he was ready to make inferences, or provide an explanation, of the Iceman's final journey.

Guiding Questions

AL What is an inference?	*An inference is a logical explanation of an observation that is drawn from prior knowledge or experience.*
OL What inference did the professor make after studying the plant evidence in the Iceman's digestive system?	*Knowing the rate at which food and pollen decompose after swallowing, the professor inferred from the plant evidence that the Iceman ate three time on the day he died.*
BL What can you infer about pollen after reading all of the evidence about the Iceman?	*Sample answer: I can infer that pollen is specific to a species of plant and can remain identifiable for thousands of years*

Visual Literacy: Figure 11

Figure 11 shows the hypothesized final journey of the Iceman, from a low alpine valley to the high mountain region where he was found. Professor Oeggl used evidence from pollen in the Iceman's digestive system to create this map. Have students study the map and answer these questions.

Ask: What do the green spots on the map represent? *The green spots represent areas that contain the types of plants that produced the pollen found in the Iceman's digestive system.*

Ask: Where did the Iceman's last journey likely begin? What evidence led to your conclusion? *His journey began in the alpine valley near the current Juval Castle. There was evidence of pollen from plants that grew only in this region.*

Conclusion

Research on the Iceman and the artifacts surrounding him helped scientists to understand how he died. Scientific inquiry often occurs over years and years, as different scientists test different hypotheses and adjust old conclusions. The story of the Iceman shows that science is an active discipline that assembles many pieces of information to obtain the most accurate conclusion possible.

Guiding Questions

AL How did scientists solve the mystery of the Iceman?	*Many scientists studied artifacts, tested different hypotheses, and analyzed data to come up with the most logical conclusion.*
OL What evidence in 2002 led scientists to revise previous conclusions about the Iceman?	*A radiological investigation revealed an arrowhead under the Iceman's left shoulder, indicating that he had died from an injury and not exposure.*
BL Do you think that the mystery of the Iceman has been completely solved? Explain.	*Sample answer: No. Scientists might discover even more evidence that will help them to revise their conclusion to make it more accurate.*

Teacher Notes

Case Study

His Highness Sheikh Mohammed Bin Rashid Al Maktoum watched as he flew by helicopter over the Saruq Al-Hadid an area which is lied on aspectacular desert land-scape of southern Dubai on the northern edge of the Great Rub al-Khali desert, with sandy dunes with different colors from its desert surroundings, It immediately comes to his mind that there is something hidden by these dark dunes, and he decided to return to the region - in 2002 - accompanied by a group of world and local archaeologists, who assured him that it was an area of historical monuments ,where Arab tribes lived 5000 years ago.

The identity of the archaeological location was a mystery, with many assumptions about the location, so many experiments were required to remove the mystery of the identity of this archaeological location. His Highness, scientists and the public wanted to know the age of this archaeological location and what kind of Living organisms has been lived in this era and what other could be finds in the archaeological location.

By examining the previous case (The Iceman's Last Journey). How can you follow and apply the same steps to confirm the theory of Sheikh Mohammed Bin Rashid that "there is something hidden around dark dunes".

Summarize it

- The *independent variable* is the factor a scientist changes to observe how it affects a *dependent variable*. A dependent variable is the factor a scientist measures or observes during an experiment.
- Scientific inquiry was used throughout the investigation of the Iceman when hypotheses, predictions, tests, analysis, and conclusions were developed.

Use Vocabulary

1 variable **DOK 1**

2 The independent variable is the factor a scientist wants to test. The dependent variable is the factor a scientist observes or measures during an experiment. A scientist changes the independent variable to observe how it affects a dependent variable **DOK 1**

Understand Key Concepts

3 D. Make a computer mo **DOK 1**

4 The control group is the group given sugar pills. The exper mental group is the group given a **DOK 2**

Interpret Graphics

5 Sample answer: Observation-The construction of the ax indicates that it is at least 4,000 years old; Prediction-If the ax is 4,000 years old, the body found is at least 4,000 years old; Test Result-Radiocarbon dating showed that the ax was 5,300 years old; Conclusion- The Iceman died around 5,300 years ago. **DOK 2**

6 The hop hornbeam blooms from March to June and it only grows in lower elevations. Because the hop hornbeam was still intact in the Iceman's stomach, he had to have died in the spring when the hop hornbeam bl **DOK 3**

Critical Thinking

7 Sample answer: Who shot the Iceman with the arrow? Why was the Iceman sh **DOK 4**

8 Sample answer: There is an assumption that he died from an injury instead of exposure to the elements. Could both have been a factor in his death? A hole in the research is who shot the arrow and w **DOK 4**

LAB Manager

Inferring from Indirect Evidence This lab can be found in the *Student Reference Handbook* and the *Activity Lab Handbook*.

Teacher Toolbox

Transparency

Focus on Content: The Iceman's last Journey Use this transparency to help students visualize the path th Iceman traveled on his last day.

Transparency available in the eTeacherEdition

Fun Fact

Examining the Iceman The body of the Iceman is kept in the South Tyrol Museum of Archaeology in Bolzano, Ita High-tech investigations have revealed that this ancien was not in good health before he died. Analysis of his fingernail has shown that he had three bouts of diseas the last six months of his life. More analysis of his intes has found whipworm eggs—an intestinal parasite.

Technology Activity

Learning More About the Iceman Help students to find the National Geographic Web site that provides more information and interactive features related to the Icem Encourage students to write a short report about some additional evidence used to understand the Iceman.

SECTION

1.2 Case Study

Discover the area of Saruq AL-Hadid

His Highness Sheikh Mohammed Bin Rashid Al Maktoum watched as he flew by helicopter over the Saruq Al-Hadid area which is lied on aspectacular desert landscape of southern Dubai on the northern edge of the Great Rub al-Khali desert, with sandy dunes with different colors from its desert surroundings, It immediately comes to his mind that there is something hidden by these dark dunes, and he decided to return to the region - in 2002 - accompanied by a group of world and local archaeologists, who assured him that it was a historical monument area , where Arab tribes lived 5000 years ago.

The identity of the archaeological location was a mystery, with many assumptions about the location , so many experiments were required to remove the mystery of the identity of this archaeological location . His Highness, scientists and the public wanted to know the age of this archaelogical location and what kind of Living organisms has been lived in this era and what other could be finds in the archaeological location.

Figure 7 His Highness Sheikh Mohammed Bin Rashid and a group from the officials at the Saruq Al-Hadid Museum.

By studying the previous case

How can you follow and apply the same steps in Iceman's study case to confirm the theory of His Highness Sheikh Mohammed Bin Rashid Al Maktoum that "there is something hidden around dark dunes ".

The identity of the body was a mystery, with many assumptions and there were also concerns about the Saruq Al-Hadid area.

Therefore, controlled trials were required to demystify identity of Saruq Al-Hadid area. Scientists and the public wanted to know the history of this area and how was the life there and wh this empty desert and other questions.

Figure 8 The location of the Saruq Alhadid within a wonderful desert nature on the south of Dubai, on the Northern edge of the Great Rub Al-Khali desert.

Identifying Variables and Constants

Observation

Hypothesis

Revised Hypothesis

Prediction

An Early Conclusion

More Observations and Revised Hypotheses

More Observations and Revised Hypotheses

Analyzing Results

Figure 9 These Effects and remains were found at the location of the Saruq Al-Hadid.

Figure 10 The archeologist examined a collection of artifacts found at the location of the Saruq Al-Hadid.

Saruq Al-Hadid.

Figure 11A group of antiquities discovered at the location of the Saruq Al-Hadid.

More Observations and Revised Hypotheses

The research teams provided Professor Oeggl with a tiny sample from the Iceman's digestive tract. He was determined to study it carefully to obtain as much information as possible. Oeggl carefully planned his scientific inquiry. He knew that he had to work quickly to avoid the decomposition of the sample and to reduce the chances of contaminating the samples.

Additional Results Analysis

Describe

Why was this particular location chosen? It lacks fresh water and and it is far from the Copper mines in the Mountains " Why this question was asked by Dr. Hussein Qandil, a Dubai archeologist.

Mapping the Saruq Al-Hadid

The Saruq Al-Hadid is one of the largest and most important sites dating back to the times of Iron Age in the Arabian Peninsula. has become a jewel crown

Archaeological sites in the Emirate of Dubai.

The site has a global importance as it opens the way to our knowledge for

Industrial activity and daily life during the Iron Age Arabian Island.

The site provides comprehensive evidence to prove the manufacture of copper alloys and works of gold and iron. An iron itself has special importance because the evidence related to the iron industry in these part of period is very rare in the

Arabian Peninsula .

Conclusion

"Saruq Al Hadidl is an important archaeological site in the UAE because it completes what we previously knew about the links with " Al Mullaha" in Sharjah, in Um Al Quwain, and Umm Al Nar in Abu Dhabi. These sites are embedded in basic blocks that align with each other to form a complete picture about the ancient history of the United Arab Emirates "

Rashad Mohammed Bukhash

Executive Director of Urban Heritage Management, Dubai Municipality

My Notes

SECTION

Review

Visualize It!

Scientific investigations often begin when someone asks a question about something observed in nature.

Scientific investigations may disprove early hypotheses or conclusions.

Summarize it!

1. How are independent variables and depe[illegible] related?

2. How is scientific inquiry used in a real-life scientific investigation?

LABManager

Case Study

Use Vocabulary

1. A factor that can have more than one value is a(n) ____________.
2. **Differentiate**tween independent and dependent variables.

Understand Key Concepts

3. Which part of scientific inquiry was NOT used in this case study?
   - A. Draw conclusions.
   - B. Make observations.
   - C. Hypothesize and predict.
   - D. Make a computer model.
4. **Determine**hich is the control group and which is the experimental group in the following scenario: Scientists are testing a new kind of aspirin to see whether it will relieve headaches. They give one group of volunteers the aspirin. They give another group of volunteers pills that look like aspirin but are actually sugar pills.

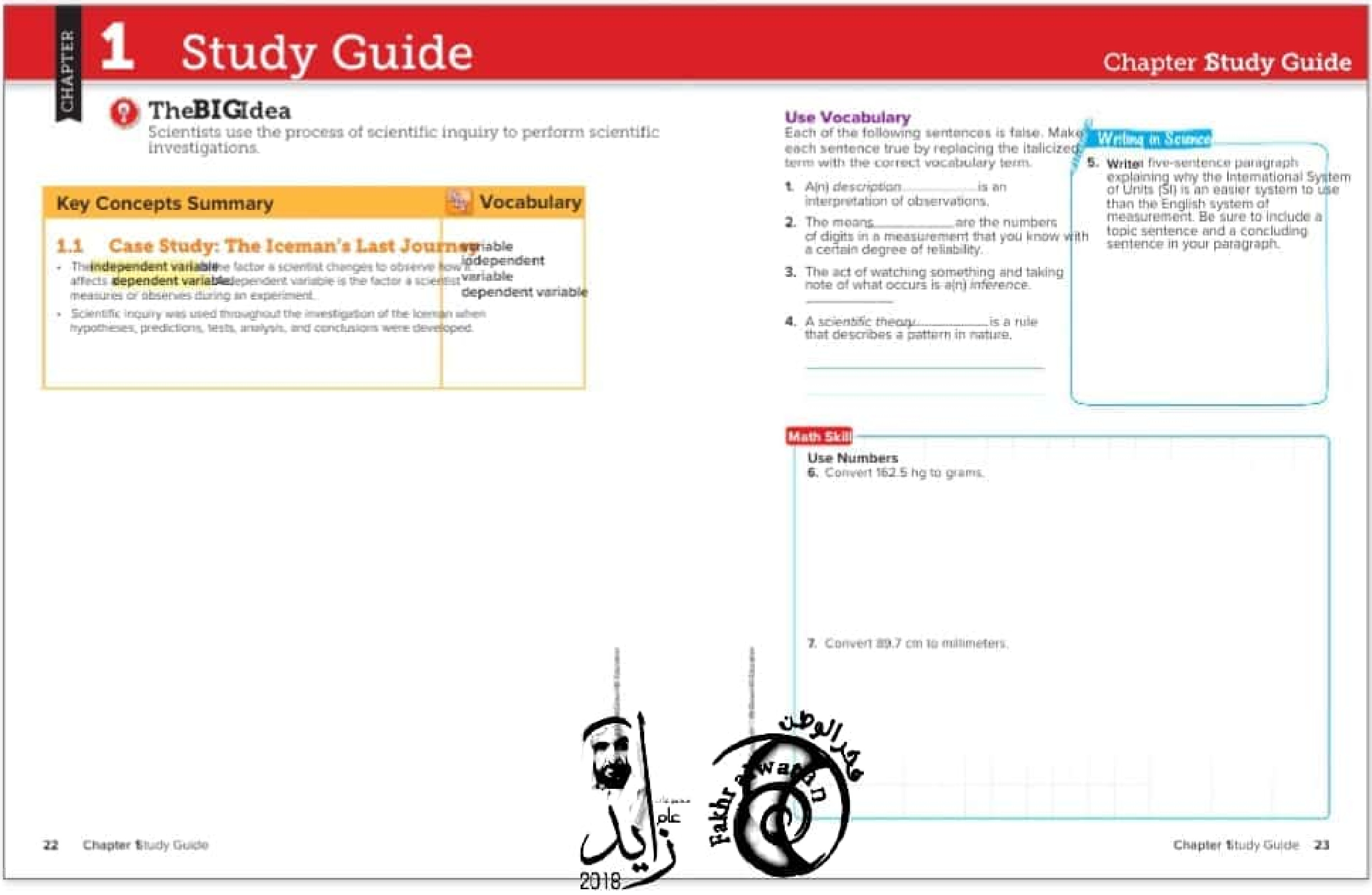
Interpret Graphics

5. **Summarize**ill in the flow chart below summarizing the sequence of scientific inquiry steps that was used in one part of the case study.

6. **Explain**What is the significance of the hop-hornbeam pollen found in the Iceman's digestive tract?

Critical Thinking

7. **Formulate**ore questions about the Iceman. What would you want to know next?
8. **Evaluate**se hypotheses and conclusions made during the study of the Iceman. Do you see anything that might be an assumption? Are there holes in the research?



CHAPTER 1 Study Guide

Chapter Study Guide

The BIG Idea
Scientists use the process of scientific inquiry to perform scientific investigations.

Key Concepts Summary | **Vocabulary**

1.1 Case Study: The Iceman's Last Journey

- The independent variable is the factor a scientist changes to observe how it affects a dependent variable. A dependent variable is the factor a scientist measures or observes during an experiment.
- Scientific inquiry was used throughout the investigation of the Iceman when hypotheses, predictions, tests, analysis, and conclusions were developed.

variable
independent variable
dependent variable

Use Vocabulary
Each of the following sentences is false. Make each sentence true by replacing the italicized term with the correct vocabulary term.

1. A(n) *description* ________ is an interpretation of observations.
2. The *means* ________ are the numbers of digits in a measurement that you know with a certain degree of reliability.
3. The act of watching something and taking note of what occurs is a(n) *inference*. ________
4. A scientific *theory* ________ is a rule that describes a pattern in nature.

Writing in Science

5. **Write** a five-sentence paragraph explaining why the International System of Units (SI) is an easier system to use than the English system of measurement. Be sure to include a topic sentence and a concluding sentence in your paragraph.

Math Skill

Use Numbers

6. Convert 162.5 hg to grams.
7. Convert 89.7 cm to millimeters.

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Chapter Study Guide 23

Key Concepts Summary

Study Strategy: Sentence Scramble

Most students enjoy playing games, which make games an ideal tool forstudying. Many games, like the sentence-scramble game described below,can be adapted to the classroom.

1. Tell students to choose five different Key Concept statements from thischapter.
2. Have students make a chart like the one below. In the first column,they should scramble the words of the five Key Concept statements they chose.
3. Ask students to exchange charts with a partner. Students should unscramble the sentence in the first column and write it in the second column.

Example:

Scrambled Sentence	Corrected Sentence
evaluate that mean statistical median sets mode and range are calculations are used to of data	Mean, median, mode, and range are statistical calculations that are used to evaluate sets of data.

Vocabulary

Study Strategy: Self-Assessment

It is important for students to know how to identify concepts and terms on which they should focus when they study. Having students work in pairs to quiz each other can help students do this. Students can use this activity to find out how well they know this chapter's vocabulary.

4. Have students form pairs. Each partner will take turns reading the definitions of the chapter's vocabulary from the Glossary.
5. The partner will then try to identify the term that matches that definition.
6. Tell students that if they did not correctly identify a term, they should write it down in their Science Journals. Next to each term they did not correctly identify, they should write the term's definition. They can use a chart like the one below.

Example:

Terms to Study	Definition
scientific law	a rule that describes a pattern in nature
variable	

Use Vocabulary

1 explanation
2 significant digits
3 observation
4 scientific law

Writing in Science

5 Student answers should contain factual information and the paragraph should be well structured.

Math Skills

6 16,250 g
7 8.97 mm

Teacher Notes

CHAPTER 1 Review

Understand Key Concepts

1. In the diagram of the process of scientific inquiry, which skill is missing from the Test Hypothesis box?
   - A. Analyze results.
   - B. Communicate results.
   - C. Make a model.
   - D. Make observations.

   Test Hypothesis
   - Design an Experiment
   - Gather and Evaluate Evidence
   - Collect Data/Record Observations

2. You have the following data set: 2, 3, 4, 4, 5, 7, and 8. Is 6 the mean, the median, the mode, or the range of the data set?
   - A. mean
   - B. median
   - C. mode
   - D. range

3. Which best describes an independent variable?
   - A. It is a factor that is not in every test.
   - B. It is a factor the investigator changes.
   - C. It is a factor you measure during a test.
   - D. It is a factor that stays the same in every test.

Critical Thinking

4. **Predict** what would happen if every scientist tried to use all the skills of scientific inquiry in the same order in every investigation.

5. **Assess** the role of measurement uncertainty in scientific investigations.

6. **Evaluate** the importance of having a control group in a scientific investigation.

The BIG Idea

7. What process do scientists use to perform scientific investigations? List and explain three of the skills involved.

8. Infer the purpose of the pink dye in the scientific investigation shown in the photo.

My Notes

24 Chapter Review

Understand Key Concepts

1 C. Make a model.

2 D. range

3 B. It is a factor the investigator changes

Critical Thinking

4 Sample Answer: Scientific progress would slow down because scientific testing would contain unnecessary steps.

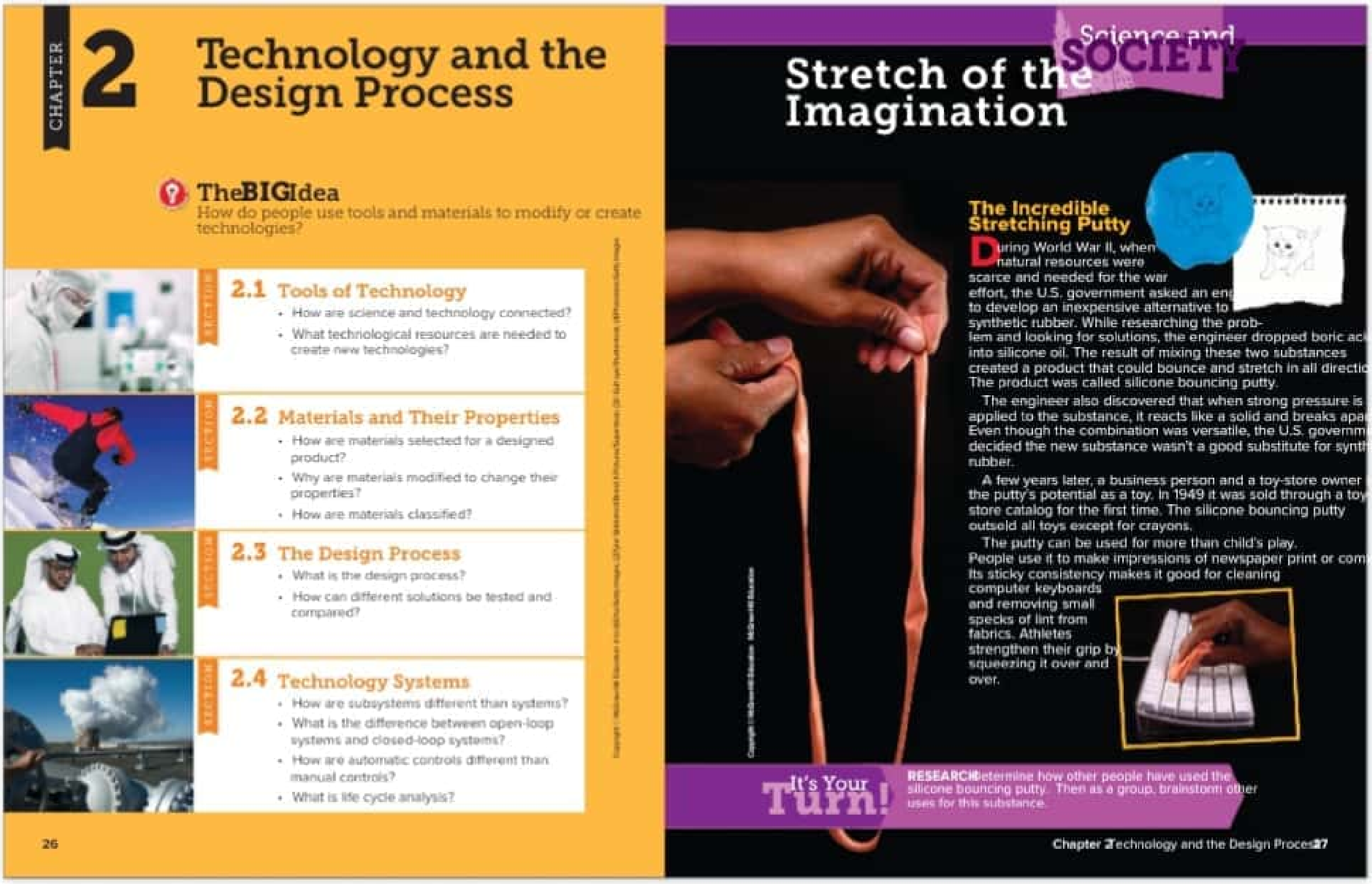
5 Sample Answer: Because measurement uncertainty is unavoidable, it must be correctly communicated to others and managed.

6 The control group reveals whether the experimental observ tions are a result of changing a variable or not.

Review

7 scientific inquiry; devising a testable hypothesis-If the hypothesis is not testable, it is of little value. devising an experiment to test the hypothesis-If the experiment is not well thought out, the results might have little value. drawing reasonable conclusions-If the conclusions do not make reasonable inferences from the data, they have no value.

8 The pink dye is an indicator that gives scientists a reference point to measure. The movement of the pink dye shows the movement of the ice.



CHAPTER 2

Technology and the Design Process

TheBIGIdea
How do people use tools and materials to modify or create technologies?

SECTION 2.1 Tools of Technology
- How are science and technology connected?
- What technological resources are needed to create new technologies?

SECTION 2.2 Materials and Their Properties
- How are materials selected for a designed product?
- Why are materials modified to change their properties?
- How are materials classified?

SECTION 2.3 The Design Process
- What is the design process?
- How can different solutions be tested and compared?

SECTION 2.4 Technology Systems
- How are subsystems different than systems?
- What is the difference between open-loop systems and closed-loop systems?
- How are automatic controls different than manual controls?
- What is life cycle analysis?

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Science and SOCIETY

Stretch of the Imagination

The Incredible Stretching Putty

During World War II, when natural resources were scarce and needed for the war effort, the U.S. government asked an en… to develop an inexpensive alternative to synthetic rubber. While researching the problem and looking for solutions, the engineer dropped boric ac… into silicone oil. The result of mixing these two substances created a product that could bounce and stretch in all directio… The product was called silicone bouncing putty.

The engineer also discovered that when strong pressure is applied to the substance, it reacts like a solid and breaks apa… Even though the combination was versatile, the U.S. governm… decided the new substance wasn't a good substitute for synth… rubber.

A few years later, a business person and a toy-store owner … the putty's potential as a toy. In 1949 it was sold through a toy store catalog for the first time. The silicone bouncing putty outsold all toys except for crayons.

The putty can be used for more than child's play. People use it to make impressions of newspaper print or com… Its sticky consistency makes it good for cleaning computer keyboards and removing small specks of lint from fabrics. Athletes strengthen their grip by squeezing it over and over.

It's Your Turn! RESEARCH Determine how other people have used the silicone bouncing putty. Then as a group, brainstorm other uses for this substance.

Chapter 2 Technology and the Design Process 27

Technology and the Design Process

TheBIGIdea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL What are some ways you use technology?	*Possible answers may include smartphones to watch videos or to listen to music or e-reader or a tablet to read books. Use this question to help students develop a greater awareness for how technology impacts individuals at home, in school, and at work.*
OL What do you think of when you hear the word technology?	*Possible answers may include computers, hybrid cars, artificial limbs, or GPS systems as technology. Use this question to assess student understanding of the meaning of technology.*
BL Why does technology keep changing?	*Possible answer may include that people come up with new ideas to do something different. Use this question to help students consider the forces that drive new designs in technology.*

Science and SOCIETY

Stretch of the Imagination

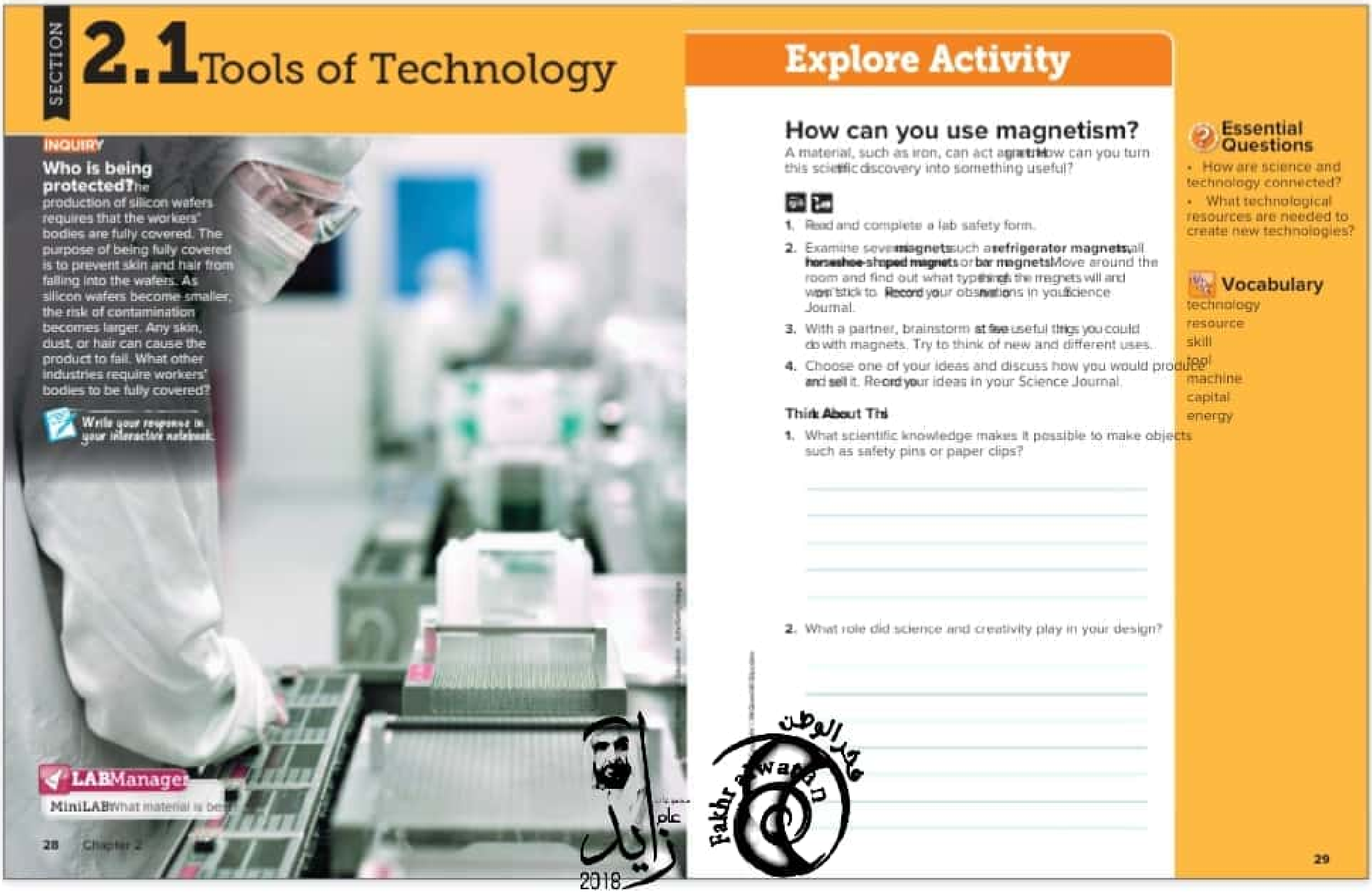
Background Information

During World War II, there were shortages of many materials. One material that was in short supply was rubber, which is a natural carbon-based polymer that comes from trees. Because of the war scientists were trying to replace carbon in polymers such as rubber with silicon. Polymers are large molecules made from mostly small molecules linked together. Various organic compounds are often attached to the polymer to control and change its physical properties.

Before You Read

Call on students to share what they know about silicone bouncing putty.

Ask: How have you used the silicone bouncing putty? *Answers will vary. Students might say they used it as a bouncing ball or use in place of tape to secure an item.*



INQUIRY

About the Photo **Who is being protected?** Explain that silicon is a naturally occurring nonmetallic element. The making of silicon wafers used for the conduction of electricity is a highly complex process that involves several different types of technology, all designed and carefully monitored by humans.

Guiding Questions

AL Why must the worker wear protective glasses?	*Protective glasses prevent contamination of the wafers and to protect the worker's eyes.*
OL What other industries require the workers to be fully covered?	*Examples of industries are nanotechnology and medical.*
BL What could the consequences be if the wafers became contaminated?	*Use this question to help students understand the importance of standards in the technology industry and that contamination or defects will cause the wafers to fail.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Use Word Parts

1. Write the word *technology* on an interactive whiteboard or the board. Draw a circle around *techno*. Explain that *techno* comes from the Greek language and means a skill or art
2. Underline *logy*. Explain that *logy* is a suffix meaning the study of. Mention other examples, such as "biology-the study of bio life" and "archeology-the study of archaic/old things". **What is the meaning of technology using its word parts?** *study of a skill or art.* **Ask: Why type of skill might we study when thinking about technology used in photography?** *skill needed to work different types of cameras.*
3. Have students add the lesson's vocabulary words to their Science Journal. Remind them to write the definition after each word as they read the lesson.

Explore Activity

How can you use magnetism?

Prep: *5 min* **Class:** *15–20 min*

Purpose
To distinguish between science and technology

Materials
Per team of 3 students: variety of magnets

Before You Begin
Assemble a variety of magnets, such as refrigerator magnets, small horseshoe-shaped, or bar magnets, and devices that use magnets such as a compass. There should be enough magnets that each team can observe and use several different shapes.

Guide the Investigation

- Have students use pairs of magnets to determine what materials the magnets will and won't stick to.
- Encourage students to brainstorm ways in which magnets can accomplish tasks. Students may begin with ways that magnets are already used and then come up with ideas of their own.

Think About This
Students may not know the answers to all questions. Encourage them to hypothesize.

1. The knowledge that metals can be pulled into the shape of a wire or bent into different shapes without breaking.
2. The inventions are all based on the scientific principle of magnetism. The use of the magnets is a product of creativity.

Teacher Notes

Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Technology

What is technology? You may have heard people say that we live in the age of technology. Many people think technology includes only items such as computers, flat-panel TVs, MRIs, space shuttles, and cell phones. Technology includes those things and much more. **Technology** *the application of scientific knowledge to benefit people*. Technology includes everything we design and use to get things done.

Reading Check

1. What is technology?

History of Technology

Technology has existed as long as humans have existed. For most of human history, technology was created by craftspeople. They used materials around them, such as trees, to build tools, homes, and furniture.

Over the years, craftspeople improved designs, developed techniques, and used new materials as they became available. Iron was once heated and hammered into shape with hand tools. Today sheets of iron are formed and cut by machines, as seen in **Figure 1**.

Figure 1 This steel slab is being cut by two welding torches.

Science and Technology

Have you ever thought about how science and technology are connected? New scientific information can lead to new products or processes. For example, finding the virus that causes a particular strain of influenza is considered science. Developing a vaccine for that influenza strain is an example of technology.

At the start of the Industrial Revolution, inventors in Scotland and England designed the steam engine. It burned wood or coal and converted chemical energy into **mechanical energy**. Steam built up pressure that moved parts to put wheels in motion. Science explained the technology of motion. Inventors used that information to develop trains with steam engines.

Imagine that you want to create a more efficient train. First you'll need to choose materials for your design based on their properties. Which materials are strong and durable, yet inexpensive and easy to get? Which materials have the least negative impact on the environment?

The more scientific knowledge you have, the better you can develop technological solutions. Some technological solutions such as high-speed trains shown in **Figure 2** take years to develop. Science depends on technology, but technology depends on science, too. Technology has to observe the principles of science, and solutions can be temporary. Science and technology are always changing due to new ideas.

Review Vocabulary

mechanical energy sum of the potential energy and the kinetic energy in a system

Key Concept Check

2. How might advancements in science affect technology?

Figure 2 High-speed trains in Japan have been continually modified since their inception in the 1930s. The first line opened in 1964.

Technology

Technology is the application of scientific knowledge to benefit people. Have students generate individual lists of five types of technology. Then, have students share their lists and write the items on the board as they are identified.

History of Technology

Have students identify examples of technology from the past, such as the wheel. Discuss how past technologies in agriculture, communications, and/or transportation improved peoples' lives. Direct student attention to Figure 1 and read the caption. Have students identify how technology helps accomplish the task.

Guiding Questions

AL **What are three examples of technology?**	*Possible answer: computers, flat-panel TVs, and space shuttles*
Reading Check What is technology?	*application of scientific knowledge to benefit people*
BL **How has technology helped civilizations to advance?**	*Possible answer: Tools used for hunting, as weapons, and for farming helped civilizations prosper and grow.*

Explain

Science and Technology

Have students read the four paragraphs. Discuss the advances that occurred in the Industrial Revolution, from everyday appliances like the vacuum cleaner and washing machine to the first automobiles and airplanes. Have students answer the questions below.

Guiding Questions

AL **Why do some technological solutions, such as the bullet train, take years to develop?**	*They are very complex and involved many different systems.*
Key Concept Check How might advancements in science affect technology?	*Greater knowledge of science can lead to new technologies.*
BL **What role do inventors play in advancing technology?**	*Inventors use existing technology and scientific knowledge to create new and improved technologies.*

Review Vocabulary

mechanical energy

Write *potential energy* + *kinetic energy* = *mechanical energy* on the board or chart paper. Remind students that potential energy is stored energy while kinetic energy is the energy of motion. **AL** **What is the sum of potential energy and kinetic energy of an object?** *mechanical energy*

Technology Resources

Developing technology requires knowledge, skills, raw materials, tools, and energy to create the products and services we want and need. The types of resources used in ancient days are still used to develop new technologies. A **resource** is *a source of supply or support*. Technological resources include:

- people
- information
- tools
- machines
- capital
- time
- materials
- energy

People

Any list of technology resources must include people. All technologies were developed by people who used their knowledge and creativity to find new solutions to existing problems. Do you watch movies on a DVD player? Its inventor developed a way to improve the image quality of videotapes.

People are also important for their skills. A **skill** is *an ability you develop when you combine knowledge and practice in order to perform an activity well.* People use their skills to convert ideas into real products or processes.

People are also the users of the products. Between the designer and the user, there are many jobs that are done by people. People build the tools and machines, set up the factories, run the machines, and package and ship the products. Other people work in the service area of technology. They sell, install, and repair these products.

Visual Check

3. What type of resource is shown below?

Figure 3 Without resources, advancement in technology and science would not be possible.

Reading Check

4. What is a skill?

Figure 4 The knowledge that helped develop computers also contributed to the creation of flat screen TVs.

Information

Why is information needed to create technology? Information can lead to knowledge, learning, and understanding. We apply information, skill, and natural resources to meet our needs and wants.

Technology can be improved with new information. Where is information found? Information can be found in many places. People find it in the library, on the Internet, or in scientific journals. Information also can be found by talking to other people or at scientific meetings.

Key Concept Check

5. Why is information important to technology?

When scientists conduct investigations, the resulting data may contribute new information or knowledge about an idea or product. With this new knowledge, engineers might improve existing technologies or develop new ones. For example, when computers were first built in the United States between 19[...] and 1951, they were very large and extremely slow. As scientific and technological knowledge about computers grew, computers became smaller and faster. Eventually, knowledge about computers led to the development of many other devices, such as flat screen TVs as shown in **Figure 4** and computer tablets.

Figure 5 Tools such as this hammer help make work easier.

Tools

People consider devices that help them perform their jobs as tools of their trade. A **tool** is *a device that increases the ability to do work.* If learning is your work, then pens, pencils, paper, and computers are some of your tools.

The first tools were handheld nonelectric tools. These tools [...] a person's ability to hold, cut, drill, bend, and h[...] as seen in **Figure 5**. People use these tools to construct [...] meet human needs and wants. These tools are [...] to [...]e other tools. Without tools, more complex technology [...] could not develop. One positive impact of improved tools is [...] tasks are done more efficiently, accurately, and safely.

Academic Vocabulary

device *(noun)* a piece of equipment designed to serve a special purpose or perform a special function

Technology Resources

Have students read the paragraph. Ask students to identify resources they need to be successful in school, such as writing utensils, computers, textbooks, and workspaces. Direct students' attention to **Figure 3** and read the caption. Use the questions below to discuss technology resources.

Guiding Questions

AL What is a resource?	*a source of supply or support*
Visual Check What resources are shown in the figure?	*people, capital, materials, energy*
BL What is true about technology resources today and in the past?	*the need for similar resources to develop technology, such as creative ideas from people, tools, and time.*

People

Direct student attention to **Figure 4** and have them read the caption. Discuss the importance of people as a technology resource.

Guiding Questions

AL What is one way you use technology?	*Possible answer: I use my cell phone to communicate with friends.*
BL How do people impact the development of technology?	*Possible answer: They build on successful ideas to improve existing technology and develop new technologies.*

Reading Check Answer A skill is an ability you develop when you combine Knowledge and practice in order to perform an activity well.

Information

Have students read the paragraphs. Write the word information on the board or chart paper. Create a list as students identify sources of information. Discuss the value of each source.

Guiding Questions

AL What do many people use as a source of information?	*the Internet, the TV, library, teachers*
Key Concept Check Why is information important to technology?	*Information can lead to new knowledge and understanding which can create new technology.*
BL Are there times when scientists may not want to share information about technology?	*Possible answer: Scientists may want to protect the technology for national security reasons or may wish to secure funding for the development of a particular technology.*

Academic Vocabulary

device

Have students identify a device used in science, one used in math, and one used in music. Ask: **What is important to remember when using the word device?** *The word can apply to many different types of technology.*

Tools

The development of tools moved from simple to complex. The first tools were all hand held and muscle powered. With tools, humans can change the materials they found in nature. Direct students' attention to **Figure 5**. Read the caption. Have students identify the task and explain how the hammer helps to accomplish it. Have students read the paragraphs and answer the questions below.

Guiding Questions

AL What is an example of a tool you use at school?	*Possible answers: pencil, pen, computer*
OL What is a tool?	*a device that increases the ability to do work*
BL What is the relationship between tools and improved technology?	*Tools help to develop more complex technology.*

Differentiated Instruction

AL **Learning About Capital** Invite a local banker to the class to explain how credit is extended to buyers. In particular, have the banker explain how loans and cred cards provide capital to individuals.

BL **Creating a Business Plan** Explain that before a new technology project is started, a business plan is develo to determine needed resources, including capital and people. Ask a local business leader to assist your class putting together a business plan for a technology stud determined should be developed.

Teacher Toolbox

Teacher Demo

Buying on Credit Set up a day when students can buy o credit. For example, students may purchase a pencil fr the store using credit, but they must pay it back the ne day with a pencil plus erasing the board as interest payment. Make sure students sign a contract as part o credit purchase. You may wish to assign students differen roles in establishing and running the business.

Math Activity

Understanding Capital Ask a math teacher to help students understand how wealth accumulates and can lost with investment in the stock market.

1. Students will pick a stock and learn its cost per share
2. Using the computer students will track the daily valu their stock for two weeks.
3. Students will create a line graph showing the value stock over the two-week period.
4. Students will then determine if an initial investment i stock resulted in accumulated wealth.

FOLDABLES

Fold a sheet of paper into eight sections. Label it as shown. Use your book to summarize information about technology resources.

Key Concept Check

6. Why do companies need capital?

Machines

How many machines have you used to**machine** a *device that makes doing work easier.* When you think of a machine you may picture a device with an engine and moving parts. However, machines can be simple. Tools, such as knives, scissors, and doorknobs, are machines used every day that make life easier. Some machines use electronic power systems. A computer is an example of an electronic machine.

Capital

To develop technology, capital is n**Capital**s *money, credit, property, or accumulated wealth.* Capital from investors and companies can buy resources. Companies hire experts and obtain materials, tools, information, and skilled and creative people to develop useful products. Capital also can come from outside sources, as illustrat**Figure 6**.

However, spending large sums of money does not guarantee success. In order to make a profit, the amount of money to manufacture the product has to be less than what the product will sell for.

Figure 6 Many individuals and businesses get their capital from banks and investment companies.

Time

Technology takes time to develop. Most food recipes [illegible] that you mix, stir, heat, or cool the contents in a specific [illegible] and for a specific amount of time. Whether you are ma[illegible] cake, building a car, or designing a new product, results will t[illegible] shape over time.

Materials

Materials used to make products are called engineering materials or production materials. They are the building blocks of our designed world.

People create materials by combining or refining natural resources. Material resources can be classified according to how they were formed. Materials can be raw, processed, manufactured, or synthetic. Some examples of material resources are shown i**Table 1**.

Reading Check

7. How are materials classified?

Table 1 Material Resources

Raw materialse materials in their natural state. They are fo[illegible] on or in the land, sea, or air. Th[illegible] include rocks, metal ores, cru[illegible] oil, coal, sand, clay, animals, an[illegible] plants.	
Processed materials natural resources that have been changed into a more useful form. They include lumber from tree[illegible] leather from animals, and ston[illegible] from rock quarries. When you look at a processed material, [illegible] can usually identify where it c[illegible] from.	
Manufactured materials created when natural resources are altered by processes that do more than change their size or shape. Examples include gasoline, paper, concrete, and metals.	
Synthetic materials created artificially. Industrial diamonds, human-made rubber, and plastics [illegible]nthetic materials.	

Table 1 All materials fit into one of these categories.

Visual Check

8. What are manufactured resources?

Machines

Have students read the paragraph. Hold up a stapler and have stu- dents explain why it is a machine. Have students identify other non-electronic machines. Examples of non-electronic machines are bicycles, screws, and scissors.

Capital

Write the word *capital* on the board or an interactive whiteboard and define it. Draw attention to **Figure 6** and read the caption. Have students read the paragraphs and then identify the four types of capital. Remind students that profit is money that remains after all expenses are paid.

Guiding Questions

AL How is cash different from credit?	*Cash is money on hand. Credit is money you promise to pay at a later date.*
Key Concept Check Why do companies need capital?	*Capital can be used to hire skilled people and obtain materials, tools, and information*
BL Why it is important for a business to make a profit?	*Without making a profit, a business will eventually run out of needed capital and may go out of business.*

Time

Explain that, though changes in technology seem to occur quickly, it takes knowledge, creativity, time, and good management of capital for technology to develop. Some technologies, such as the Japanese bullet train, took years to develop.

Guiding Questions

AL How do you learn about changes in technology?	*advertisements, information from friends and teachers, magazines*
OL What is the relationship between time and technology advances?	*Changes in a particular technology take time to develop.*
BL What might happen if enough time is not given to the design of a new product?	*It could fail or cause harm.*

Figure 7 The temperature of a lightning bolt is five times hotter than the surface of the Sun.

Energy

How would you define energy? You might say that eating a plate of spaghetti gives you energy. You also might say that you have a lot of energy. Do you realize that a fire, a bouncing ball, and a tank of gasoline also have energy?

The word *energy* comes from the ancient Greek word *energos*, which means active. You probably have used the word *energy* in the same way. When you say you have a lot of energy, what does this mean? **Energy** is *the ability to cause change*. For example, you use energy when you change the speed of a bicycle by pedaling faster or when you put on the brakes. The energy in a thunderstorm produces lightning, shown in **Figure 7**, which lights up the sky and produces thunder that can rattle windows.

Energy does not usually exist naturally in a form humans can directly use. For example, coal is a source of energy, but the coal has to be processed. Technology makes it possible to find and release the energy in the coal, and then put that energy to work. Technologists are always looking for new and better ways to use energy resources.

Reading Check

5. What is energy?

Describe

List the main ideas from this section in the lines below.

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SECTION

2.1 Review

Visualize It!

Technology was developed because people had ideas they turned into useful devices.

Resources are used to create the products and services we want and need. Without resources, science and technology would not advance.

Companies buy resources needed to create new technology. They hire people with the knowledge and skill to make products.

Summarize it!

1. How are science and technology connected?

2. What technological resources are needed to create new technologies?

Section 2.1 Tools of Technology 37

Energy

Write the word *energy* on the board or chart paper. Have students skim the paragraphs to find the definition. Push a chair to change its position. Explain that energy was used to change the position of the chair. Direct student attention to **Figure 7** and have them read the caption. Discuss the energy released by a lightning bolt and the change it can cause when it strikes a tree or building.

Guiding Questions

AL	What is an example of energy?	*fire*
	Reading Check What is energy?	*the ability to cause change*
BL	Why is it important to find new technologies to use energy resources?	*Energy resources usually need to processed in order for humans to use it. Humans consume so much energy, finding efficient and clean ways to provide this energy is important.*

Describe Answer: Student answers will vary.

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Science and Technology
- Technology Resources

Tools of Technology

Use Vocabulary

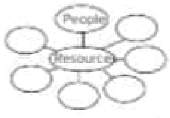
1. **Define** *resource* in your own words.
2. The ability to do work is ______.
3. **Use the term** *technology* in a sentence.

Understand Key Concepts

4. Which material resource is found in a plastic toy?
   - A. manufactured materials
   - B. processed materials
   - C. raw materials
   - D. synthetic materials
5. **Discuss** how one technology has changed in your lifetime.

Interpret Graphics

6. **Summarize** Copy and fill in the graphic organizer listing the resources needed for technology.



7. **Explain** why the type of resource shown below is important in developing new technology.

Critical Thinking

8. **Infer** Why is skill important when creating technology?
9. **Infer** What could happen if no one understood the science behind a technology they used?

My Notes

Use Vocabulary

1. A resource is something that gives help to a system Information can be a resource. DOK 1
2. energy DOK 1
3. Technology is anything and everything we design and use to get things done. DOK 2

Understand Key Concepts

4. D. synthetic materials DOK 2
5. Accept all reasonable answers. Possible answer: Television has changed in my life time. The TV signals used to be sent as analog; now they are digital. TV sets used to be big and heavy because of the picture tube. Now TVs are lighter and thin DOK 3

Interpret Graphics

6. information, tools/machines, capital, energy, materials, time DOK 2
7. The image represents capital or money. Capital is needed to buy other resources and to hire people DOK 3

Critical Thinking

8. Skilled people make better use of resources (less time, less wasted materials, etc.), and the products they produced are of better quality. DOK 3
9. People would not have the knowledge needed to maintain or improve the technology. DOK 4

SECTION

2.2 Materials and Their Properties

INQUIRY

Technology on the Slopes Do you know that snowboards are made of several layers of materials? The core is usually made of wood with layers of fiberglass above and below the wood. The bottom layer is a polyethylene plastic that slides easily over snow. What other products do you think are made of fiberglass?

Write your response in your interactive notebook.

LABManager

MiniLAB How can you model a ceramic material?

40 Chapter 2

Explore Activity

What are the properties of materials?

When an engineer designs a vehicle, bridge, or building, the materials used for construction must be selected to suit the function. Can the manufacturing process affect a material's performance?

1. Read and complete a lab safety form.
2. Using tongs, hold a 5-cm piece of steel wire in a lab burner flame until the wire glows red-hot. Continue to hold for 30 seconds.
3. Quickly drop the hot wire into a beaker of cold water.
4. Repeat step 1 with another 5-cm piece of steel wire, but place this hot wire on a heat-proof surface to cool instead of in water.
5. After both pieces of wire are cool, then try to bend them. Write your observations in your Science Journal.

Think About This

1. Compare and contrast the flexibility of the two wires.

Essential Questions

- How are materials selected for a designed product?
- Why are materials modified to change their proerties?
- How are materials classified?

Vocabulary

physical property
chemical property
mechanical property
polymers
composite material
alloy

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INQUIRY

About the Photo Technology on the Slopes Snowboards are built with different properties based on the type of snowboarding the rider wants. The snowboard designs are tested and adjusted to achieve the desired results. Explain that humans are essential in making sure technology works efficiently. Have students answer the following questions.

Guiding Questions

AL Why does the snowboard slide over the snow?	*A combination of gravity and the smooth polyethylene plastic surface allow the snowboard to easily slide over the snow. Use this question to begin discussion of the physical properties of the snowboard and the snow.*
OL What other products do you think are made of fiberglass?	*Possible answers: bathtubs, car bodies, outdoor furniture*
BL What considerations do you think are made when choosing material for a snowboard?	*Possible answer: friction reduction, durability, flexibility, density, hardness. Use this question to help students analyze the importance of materials in the design of a product.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Associations

Associating words with images can help students understand and recall scientific words.

1. Write the word *physical* on the board or chart paper. Hold up a pencil. **Ask: What are some physical characteristics of this pencil?** *hard, yellow, smooth*

   Explain that these characteristics are called properties because they belong to the object, but in a different way then we think of a person owning a house. Use a few examples comparing the two uses of the term.

When thinking about a material's physical, chemical, or mechanical properties, remember that the properties describe the characteristics of the material.

2. Have students add the lesson's vocabulary words to their Science Journal. Remind them to write the definition after each word as they read the lesson.

Teacher Notes

Explore Activity

What are the properties of materials?

Prep: *5 min* **Class:** *15 min*

Purpose
To investigate how metals may respond to fast and slow temperature change.

Materials
lab burner, tongs, several beakers of ice water, 18-gauge steel wire

Guide the Investigation

- Point out that both wire pieces are heated to the same temperature, so the only variable is the rate at which they cool. Remind students that heating metals to high temperature and then allowing them to cool occurs in engines and heating elements.
- **Ask students** what happened to the atoms in the metal as it was heated. *The atoms began to move faster and their relationship to each other changed and weakened.*
- **Ask students** why cooling quickly might not restore the flexibility to the metal wire. *The heated atoms were not given time to return to their original stable position.*

Think About This

1. Before heating, both wires were somewhat flexible. After being heated, then cooled, the wire that cooled slowly was still somewhat flexible. However, the wire that was cooled quickly became brittle and snapped easily *when bent.*

Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Properties of Materials

How does a scientist or an engineer decide which material is best for a particular use? Each material has chemical, physical, and mechanical properties. Scientists review the material's properties to determine its usefulness. For example, the covering on an electrical wire is an insulator. Scientists consider the material's electrical properties when selecting a material to cover the electrical wire.

Physical Properties

The physical properties of materials are important to consider when evaluating materials. A **physical property** is a *characteristic that can be observed or measured without changing the identity of the material.* Physical properties include magnetism, conductivity, density, solubility, melting point, and boiling point. One physical property of some metals is attraction to a magnet, such as the one shown in **Figure 8**.

Figure 8 This magnet pulls scrap metal that can be saved from the rest of the debris.

Reading Check

1. Name additional physical properties that should be considered when evaluating materials.

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Chemical Properties

You probably have seen the warnings at gasoline stations that say gasoline is a flammable (FLA muh buhl) liquid. That means the gas has the tendency to burn. Flammability is a chemical property because burning produces a new substance. A **chemical property** is *the ability or inability of a substance to combine with or change into one or more new substances.* The ability to rust is also a chemical property, as shown in **Figure 9**.

Figure 9 This car body has corroded because of its exposure to water and oxygen. When selecting materials, it is important to evaluate the environmental conditions in which a material is going to be used.

Mechanical Properties

Our world is filled with many useful and unusual materials. These materials are used to produce different products because they have different properties. In addition to chemical and physical properties, materials also have mechanical properties. **Mechanical properties** are *characteristics that determine how a material reacts to forces.* By testing mechanical properties, an engineer can learn about materials and determine the usefulness and product life of those materials. The four basic mechanical properties are shown in **Table 2**.

Visual Check

2. Which mechanical property describes a material's ability to withstand a force such as compression?

Table 2 Engineers check a material's properties to determine whether it is suitable for a particular use.

Table 2 Mechanical Properties	
	Strength The strength of a material is determined by how it withstands forces such as tension, compression, shear, and twisting.
	Elasticity Elasticity is a material's ability to stretch out of shape and return to its original shape.
	Hardness The hardness of a material is determined by a material's ability to withstand scratches, dents, and cuts.
	Flexibility This characteristic is the ability to resist breaking due to bending.

Section 2.2 Materials and Their Properties 43

Properties of Materials

Review with students that all objects have physical properties. Then have a student describe the physical properties of an object in the room. Have other students identify the object. Write *physical, chemical,* and *mechanical* on the board. Remind students that materials have all three properties.

Physical Properties

Have students read the paragraph and define *physical properties.* Write the definition on the board. Direct student attention to **Figure 8** and read the caption. Then have students answer the following questions.

Guiding Questions

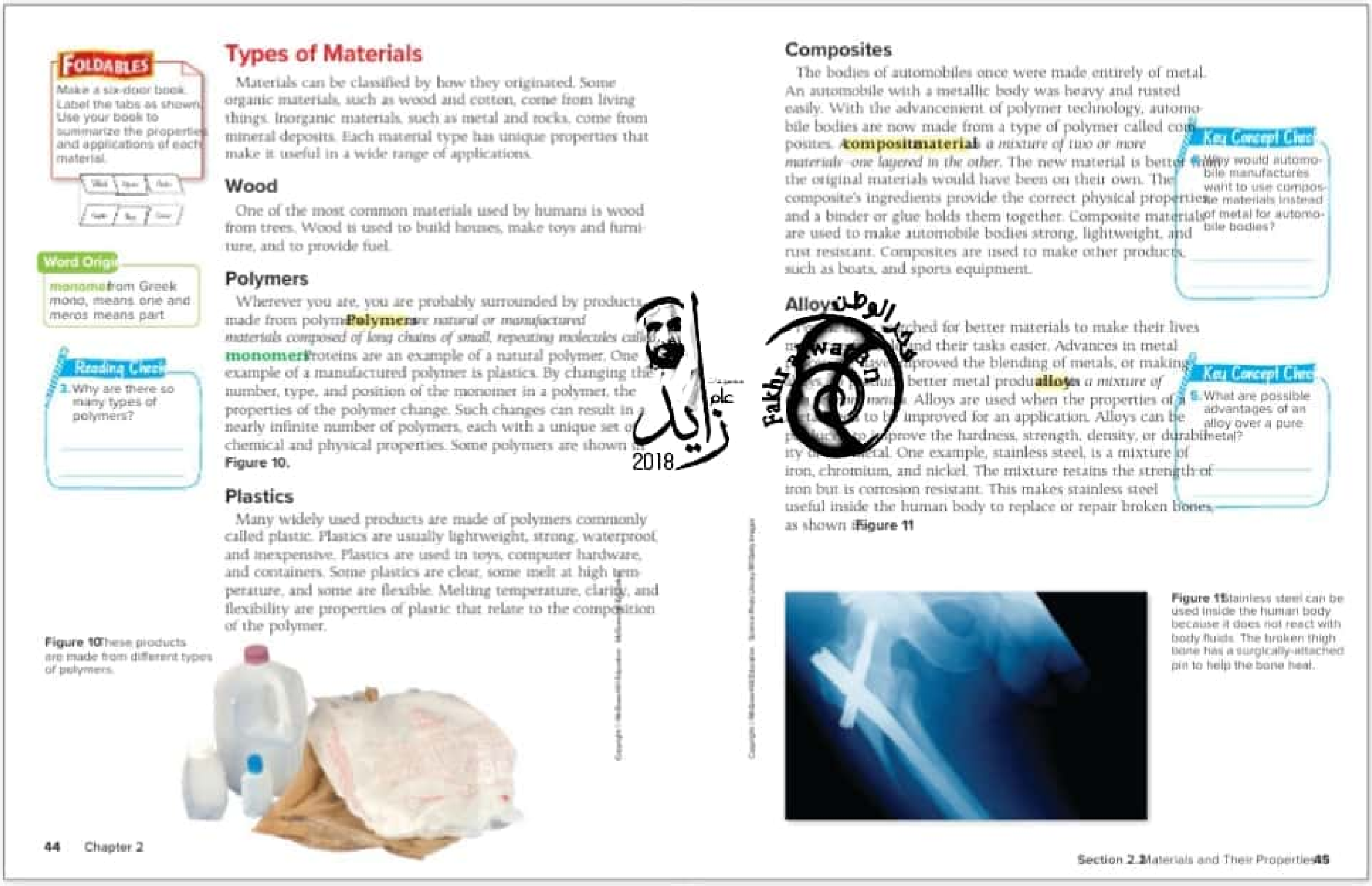
AL	What is a physical property of some metals?	*Possible answers: magnetism, luster, malleability, ductility*
	Reading Check Name additional physical properties that should be considered when evaluating materials?	*Possible answers: shape, color, size, magnetism*
BL	Which physical property would be most important to evaluate when choosing materials for a racing bike? Why?	*Possible answer: density; A high density material could require more expenditure of energy by the rider.*

Chemical Properties

Have students read the paragraph. Draw their attention to **Figure 9**. Have students describe the chemical change that occurred to the car's material. Write the definition of chemical property on the board near the definition of physical property. Have students answer the questions below.

Guiding Questions

AL	Which type of property gives a material the ability to change into another substance?	*chemical property*
OL	What is a chemical property?	*the ability or inability of a substance to combine with or change into one or more new substances.*
BL	Why is the ability to rust a chemical property?	*because a new substance is produced as a result of rusting*



FOLDABLES

Make a six-door book. Label the tabs as shown. Use your book to summarize the properties and applications of each material.

Types of Materials

Materials can be classified by how they originated. Some organic materials, such as wood and cotton, come from living things. Inorganic materials, such as metal and rocks, come from mineral deposits. Each material type has unique properties that make it useful in a wide range of applications.

Wood

One of the most common materials used by humans is wood from trees. Wood is used to build houses, make toys and furniture, and to provide fuel.

Word Origin

monomer from Greek mono, means one and meros means part

Polymers

Wherever you are, you are probably surrounded by products made from polymers. **Polymers** *are natural or manufactured materials composed of long chains of small, repeating molecules called* **monomers**. Proteins are an example of a natural polymer. One example of a manufactured polymer is plastics. By changing the number, type, and position of the monomer in a polymer, the properties of the polymer change. Such changes can result in a nearly infinite number of polymers, each with a unique set of chemical and physical properties. Some polymers are shown in **Figure 10.**

Reading Check

3. Why are there so many types of polymers?

Plastics

Many widely used products are made of polymers commonly called plastic. Plastics are usually lightweight, strong, waterproof, and inexpensive. Plastics are used in toys, computer hardware, and containers. Some plastics are clear, some melt at high temperature, and some are flexible. Melting temperature, clarity, and flexibility are properties of plastic that relate to the composition of the polymer.

Figure 10 These products are made from different types of polymers.

Composites

The bodies of automobiles once were made entirely of metal. An automobile with a metallic body was heavy and rusted easily. With the advancement of polymer technology, automobile bodies are now made from a type of polymer called composites. A **composite material** *is a mixture of two or more materials—one layered in the other.* The new material is better than the original materials would have been on their own. The composite's ingredients provide the correct physical properties and a binder or glue holds them together. Composite materials are used to make automobile bodies strong, lightweight, and rust resistant. Composites are used to make other products, such as boats, and sports equipment.

Key Concept Check

4. Why would automobile manufactures want to use composite materials instead of metal for automobile bodies?

Alloys

[illegible] searched for better materials to make their lives [illegible] and their tasks easier. Advances in metal [illegible] improved the blending of metals, or making [illegible] better metal products. **Alloys** *are a mixture of* [illegible] *metals*. Alloys are used when the properties of a [illegible] to be improved for an application. Alloys can be [illegible] to improve the hardness, strength, density, or durability [illegible] metal. One example, stainless steel, is a mixture of iron, chromium, and nickel. The mixture retains the strength of iron but is corrosion resistant. This makes stainless steel useful inside the human body to replace or repair broken bones, as shown in **Figure 11**.

Key Concept Check

5. What are possible advantages of an alloy over a pure metal?

Figure 11 Stainless steel can be used inside the human body because it does not react with body fluids. The broken thigh bone has a surgically-attached pin to help the bone heal.

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Section 2.2 Materials and Their Properties 45

Types of Materials

Write *organic* and *inorganic* on the board. Have students identify materials that fit in both categories. Create a chart on the interactive whiteboard as the materials are identified. Compare and contrast the properties of selected items.

Word Origin

monomer

Ask: **What two Greek words make up the word *monomer*?** *Mono means one and meros means part.* **Together, what do these two Greek words mean?** *one part*

Wood and Polymers

Direct student attention to **Figure 10** and have them read the caption. Have students identify the items. After students read the two paragraphs, discuss with them what makes polymers different. Use the questions below to assess students' comprehension.

Guiding Questions

AL	What are some uses for wood?	*Possible answers: build houses, make toys and furniture, make pencils*
OL	What is the relationship between polymers and monomers?	*Polymers are made up of repeating molecules called monomers.*
	Reading Check Why are there so many types of polymers?	*Changing the number, type, and position of the monomer changes the properties of the polymer. Such changes can result in a large number of different polymers.*

Plastics

Plastics are widely used for many products because they have desirable properties. They can be lightweight, waterproof, strong, and inexpensive. Transparency, melting temperature, and flexibility are properties of plastics that relate to the composition of the polymer. Have students read the paragraph and identify the properties of plastic. Then have students identify products in the classroom made from plastic.

Guiding Questions

AL	What type of material is plastic?	*a polymer*
OL	What are three properties of plastic?	*melting temperature, clarity, flexibility*
BL	What defines the properties of a particular plastic?	*composition of the polymer that makes up the plastic*

Composites

Write *composites* on the board and read its definition. Draw a Venn diagram on the board to explain composites by drawing two overlapping circles. Write gravel in one circle, cement in the other circle, and concrete (the composite) in the center overlap. Have students answer the following questions.

Guiding Questions

AL What is a composite?	*a mixture of two or more materials, with one layered in the other*
Key Concept Check Why would automobile manufacturers want to use composite materials instead of metal for automobile bodies?	*Using a composite material for the automobile body would make the car lighter and rust resistant.*
BL What is the advantage of using composites in product production?	*Possible answer: Composites provide the correct physical properties needed for a product's design.*

Alloys

Steel is mostly iron, but with the addition of other elements, the properties of the resulting alloy can be changed. Direct attention to **Figure 13** and read the caption. Explain that stainless steel is an alloy. Have students read the paragraphs. Refer to **Figure 11** and discuss the medical advantages of using stainless steel for medical purposes.

Guiding Questions

AL What is an alloy?	*a mixture of two or more metals*
Key Concept Check What are possible advantages of an alloy over a pure metal?	*Alloys can be produced to improve the metal's properties.*
BL What properties of metals can alloys improve?	*hardness, strength, density, durability*

Differentiated Instruction

AL **Learning about Ceramics** Invite the school art teacher or a local potter to class to explain how ceramics are m If possible, provide an opportunity for students to make ceramic object. Discuss the clay's physical properties a students work with it.

BL **Composites** Explain that the snowboard pictured in th lesson opener is made from composite materials. Divide class into teams. Have each team research a product u in the sports industry made from a composite. Students should create a diagram of the composite materials use the product and make suggestions for improvements in products' design. Have student teams share their work the class.

Teacher Toolbox

Teacher Demo

Stainless Steel Provide a variety of common stainless ste objects, such as a fork, cooking pan, baking pan, mixing bowls, and other utensils. Explain that stainless steel is alloy made of chromium, iron, and other metals. Discus with students that the chromium in stainless steel reac with oxygen making it slow to rust and easy to clean. Present a stainless steel object and a piece of steel wo that have been placed in separate small amounts of wa for three days. Have students observe the difference in appearance of the items. Discuss the advantages of stainless steel over regular steel for everyday utensils.

Reading Strategy

Taking Notes Draw the following graphic organizer on th board and have students copy it. Create a row for each of material. Have students complete the chart for woo polymers, plastics, composites, alloys, and ceramics. Cr student pairs and have students share their charts.

Material Type	Important Details

Figure 12 Early ceramic materials were made from clay that was heated to make a strong, rigid material.

Ceramics

This group of materials is similar to alloys in that they are mixtures that are produced to achieve desired properties. Ceramics are made from dried clay or clay-like materials. The clay is molded, as shown in **Figure 12**, then heated to a high temperature in an oven to create the final product. Ceramics are strong despite their brittleness. The properties of ceramics can be customized for a wide variety of applications such as sandpaper, pottery, dinnerware, and materials used in furnaces and space shuttles.

Reading Check

6. How are ceramics and alloys similar?

Describe

List the main ideas from this section in the lines below.

46 Chapter 2

SECTION

2.2 Review

Visualize It!

All materials have physical, chemical, and mechanical properties. These properties determine the usefulness of the materials.

Many types of materials, such as plastics and alloys, are used to make products. Each material has unique properties that make it useful in a wide range of applications.

Summarize it!

1. How are materials selected for a designed product?

2. Why are materials modified to change their properties?

3. How are materials classified?

Section 2.2 Materials and Their Properties 47

Ceramics

Have students read the paragraph and caption for **Figure 12**. Then have students share their experiences with making ceramics or familiarity with ceramic products. Have students identify the physical properties of ceramics.

Guiding Questions

AL What materials make up ceramics?	*dried clay or clay-like materials*
Reading Check How are ceramics and alloys similar?	*Ceramics and alloys are both mixtures designed to produce desired properties.*
BL What process causes the clay to change from a material that can be molded to a material that is strong and rigid?	*heating the clay*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which key concept does each image relate to?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Physical Properties
- Mechanical Properties
- Types of Materials

Materials and Their Properties

Use Vocabulary

1. A(n) ______ is a characteristic that determines how a material reacts to forces.

2. **Define** *alloy* in your own words.

3. **Use the term** *physical property* in a complete sentence.

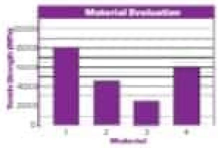
Understand Key Concepts

4. Which does NOT have modified properties?
   A. alloys C. metals
   B. ceramics D. polymers

5. **Explain** how you would classify a material that contains a mixture of three metals.

Interpret Graphics

6. **Analyze** Tensile strength is a measure of the amount of pulling stress an object can withstand before it breaks. Using the graph, which material should be considered for a product that must have the highest tensile strength?



7. **Summarize Information** Copy the graphic organizer below to give examples of the various properties used to select materials.

Properties	Examples
Physical properties	
Chemical properties	
Mechanical properties	

Critical Thinking

8. If you were designing a skyscraper in an earthquake zone, what properties would the building materials need?

My Notes

Use Vocabulary

1. mechanical property **DOK 1**

2. Alloys are mixtures of two or more metals. **DOK 1**

3. Possible answer: Physical property is a characteristic that can be observed or measured without changing identity of the material. **DOK 2**

Understand Key Concepts

4. C. metals **DOK 2**

5. The mixture would be classified as an alloy because an alloy is a mixture of two or more metals. **DOK 3**

Interpret Graphics

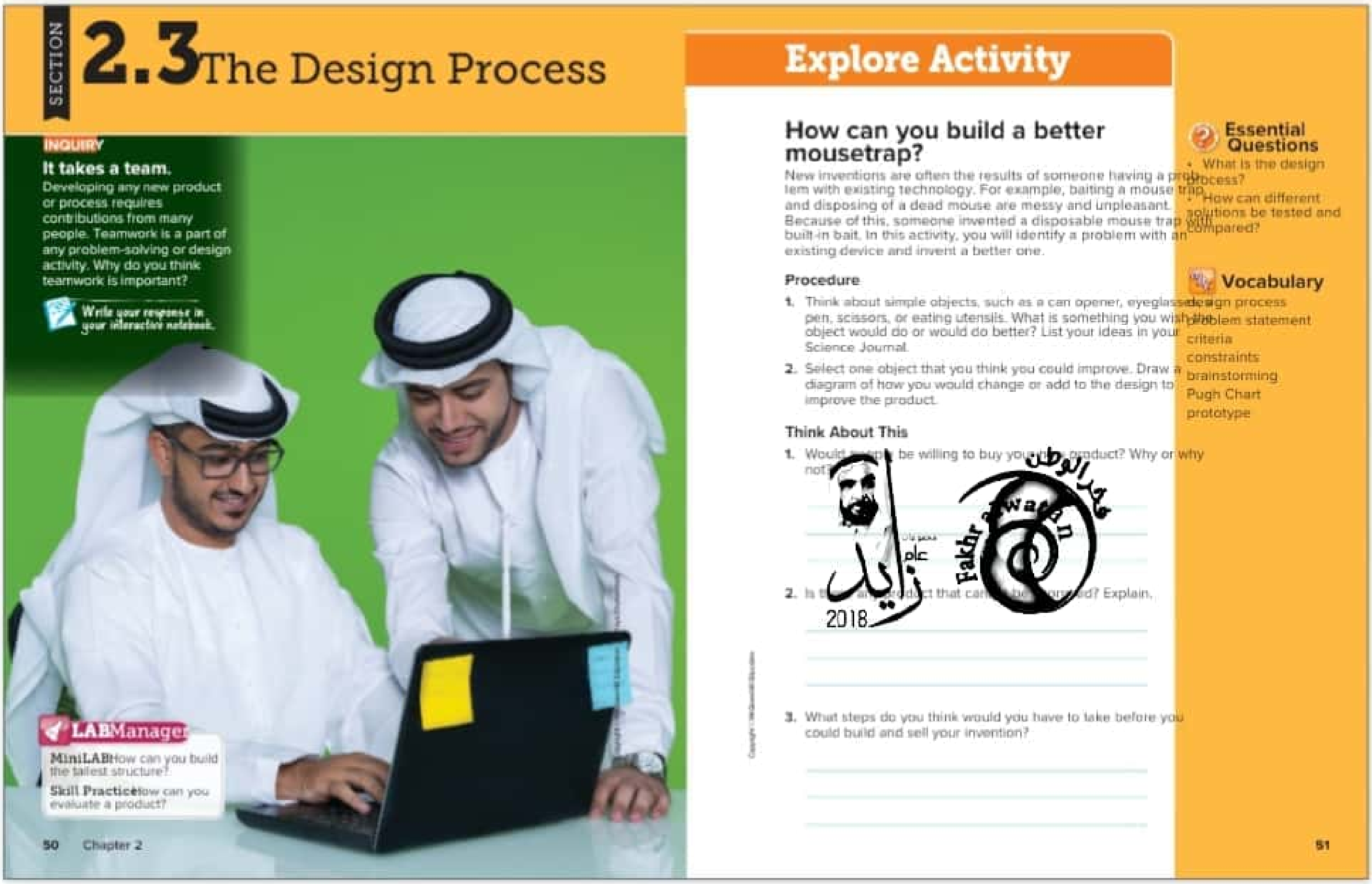
6. material **DOK 2**

7. **DOK 3**

Properties	Examples
Physical properties	Possible answers: conductivity, density, melting point, solubility
Chemical properties	Possible answers: ability to burn, ability to rust
Mechanical properties	Possible answers: strength, elasticity, hardness, fatigue

Critical Thinking

8. The materials would need strength to support the weight of the structure and flexibility to withstand the forces generated by the earthquake. **DOK 4**



SECTION 2.3 The Design Process

INQUIRY

It takes a team. Developing any new product or process requires contributions from many people. Teamwork is a part of any problem-solving or design activity. Why do you think teamwork is important?

Write your response in your interactive notebook.

LABManager

MiniLAB How can you build the tallest structure?

Skill Practice How can you evaluate a product?

50 Chapter 2

Explore Activity

How can you build a better mousetrap?

New inventions are often the results of someone having a problem with existing technology. For example, baiting a mouse trap and disposing of a dead mouse are messy and unpleasant. Because of this, someone invented a disposable mouse trap with built-in bait. In this activity, you will identify a problem with an existing device and invent a better one.

Procedure

1. Think about simple objects, such as a can opener, eyeglasses, pen, scissors, or eating utensils. What is something you wish the object would do or would do better? List your ideas in your Science Journal.
2. Select one object that you think you could improve. Draw a diagram of how you would change or add to the design to improve the product.

Think About This

1. Would people be willing to buy your new product? Why or why not?
2. Is there any product that cannot be improved? Explain.
3. What steps do you think would you have to take before you could build and sell your invention?

Essential Questions

- What is the design process?
- How can different solutions be tested and compared?

Vocabulary

design process
problem statement
criteria
constraints
brainstorming
Pugh Chart
prototype

51

INQUIRY

About the Photo **It takes a team.** Have students discuss times when teamwork is needed. Make a connection with the teamwork needed in sports to the importance of teamwork in solving problems or creating a new product or in certain jobs, like firefighting. Ask the following questions.

Guiding Questions

AL	What is teamwork?	*Use this question to begin discussion on how teamwork involves several individuals sharing ideas.*
OL	Why do you think teamwork is important?	*People have different ideas and see things differently.*
BL	What advantage does teamwork have over individual problem solving?	*Use this question to help students think about the advantages of having a team share and critique ideas.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Compound Words

Compound words are formed by combining two words that form a new meaning when placed together.

1. Write the word *brainstorming* on the board or chart paper. **Ask:** **What two words do you find in the word brainstorming?** brain and storming
2. Circle brain and underline storming. **What is the meaning of brain?** organ that controls human systems and thought **Ask:** **What is the meaning of storming?** something that occurs with great force **Ask:** **What do you think the word brainstorming means?** when a lot of thinking occurs by one of more people
3. Explain that brainstorming is a process where individuals spend time developing and sharing ideas to solve problems or create a plan of action.
4. Have students add the lesson's vocabulary words to their Science Journal. Remind them to write the definition after each word as they read the lesson.

Explore Activity

How can you build a better mousetrap?

Prep: *none* **Class:** *20 min*

Purpose
To have students identify a problem and a possible solution.

Materials per team
paper, pencils or pens

Before You Begin
Ask students what it means to build a better mousetrap. Students should say that it means making an existing product better. Display a simple object, such as a can opener. Ask students how they might improve the design to make it easier to use, more efficient, or to do something more than it already does.

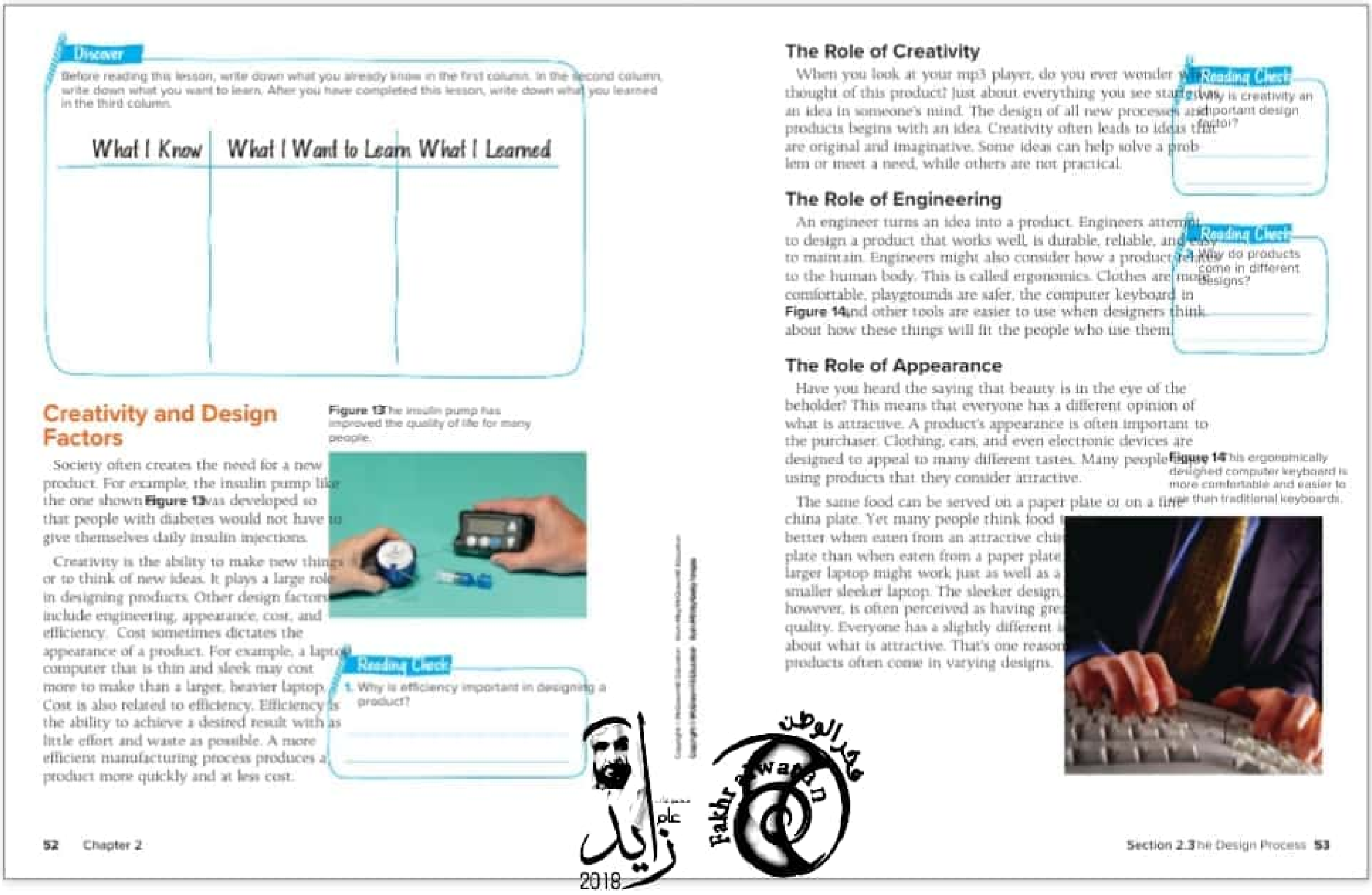
Guide the Investigation

- To get students thinking about what they might improve, have them think about objects they don't enjoy or have a hard time using.
- Encourage students to think about ordinary things that they take for granted and how they might be improved.
- Challenge students to come up with ideas that are different from anything they've seen before. Help them understand the possibility for invention is all around them.

Think About This

1. Answers will vary. If the students have developed an idea that is much better than the existing product and not too expensive, it might be easy to sell it. If it's not useful by a lot of people or too expensive, people are less likely to buy it.
2. Answers will vary. Students should recognize that almost everything can be improved in some way. Help students see that an improvement could be something that benefits the environment or makes it easier to produce, but leaves the object just as useful.
3. **Key Concept** Students should recognize that they would have to consider things like what material they would use, where they would get it, how much it would cost to buy the materials, what tools they would need to make it, what kind of skill people would need to make it, how long it would take, and how it would be packaged.

Teacher Notes



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Creativity and Design Factors

Society often creates the need for a new product. For example, the insulin pump like the one shown in **Figure 13** was developed so that people with diabetes would not have to give themselves daily insulin injections.

Figure 13 The insulin pump has improved the quality of life for many people.

Creativity is the ability to make new things or to think of new ideas. It plays a large role in designing products. Other design factors include engineering, appearance, cost, and efficiency. Cost sometimes dictates the appearance of a product. For example, a laptop computer that is thin and sleek may cost more to make than a larger, heavier laptop. Cost is also related to efficiency. Efficiency is the ability to achieve a desired result with as little effort and waste as possible. A more efficient manufacturing process produces a product more quickly and at less cost.

Reading Check

1. Why is efficiency important in designing a product?

52 Chapter 2

The Role of Creativity

When you look at your mp3 player, do you ever wonder who thought of this product? Just about everything you see started as an idea in someone's mind. The design of all new processes and products begins with an idea. Creativity often leads to ideas that are original and imaginative. Some ideas can help solve a problem or meet a need, while others are not practical.

Reading Check

2. Why is creativity an important design factor?

The Role of Engineering

An engineer turns an idea into a product. Engineers attempt to design a product that works well, is durable, reliable, and easy to maintain. Engineers might also consider how a product relates to the human body. This is called ergonomics. Clothes are more comfortable, playgrounds are safer, the computer keyboard in **Figure 14**, and other tools are easier to use when designers think about how these things will fit the people who use them.

Reading Check

3. Why do products come in different designs?

The Role of Appearance

Have you heard the saying that beauty is in the eye of the beholder? This means that everyone has a different opinion of what is attractive. A product's appearance is often important to the purchaser. Clothing, cars, and even electronic devices are designed to appeal to many different tastes. Many people enjoy using products that they consider attractive.

The same food can be served on a paper plate or on a fine china plate. Yet many people think food tastes better when eaten from an attractive china plate than when eaten from a paper plate. A larger laptop might work just as well as a smaller sleeker laptop. The sleeker design, however, is often perceived as having greater quality. Everyone has a slightly different idea about what is attractive. That's one reason products often come in varying designs.

Figure 14 This ergonomically designed computer keyboard is more comfortable and easier to use than traditional keyboards.

Section 2.3 The Design Process 53

Explain

Creativity and Design Factors

Write *creativity* on the board or chart paper. Have students define creativity. Direct student attention to **Figure 13** and read the caption. Have students consider the creativity and problem solving needed when designing a product such as the insulin pump.

Guiding Questions

AL What is efficiency?	*the ability to achieve a desired result with as little effort and waste as possible*
Reading Check Why is efficiency important in designing a product?	*Efficiency can reduce the cost of a product because materials are not being wasted.*
BL What role can cost play in a product's design?	*It can determine the appearance of a product.*

The Role of Creativity

Have students identify a creative product or idea. Discuss if the product or idea solves a problem or meets a need. Talk about the imagination needed for the initial idea and why the product or idea is considered creative. Have students read the paragraph and caption for **Figure 14**.

Guiding Questions

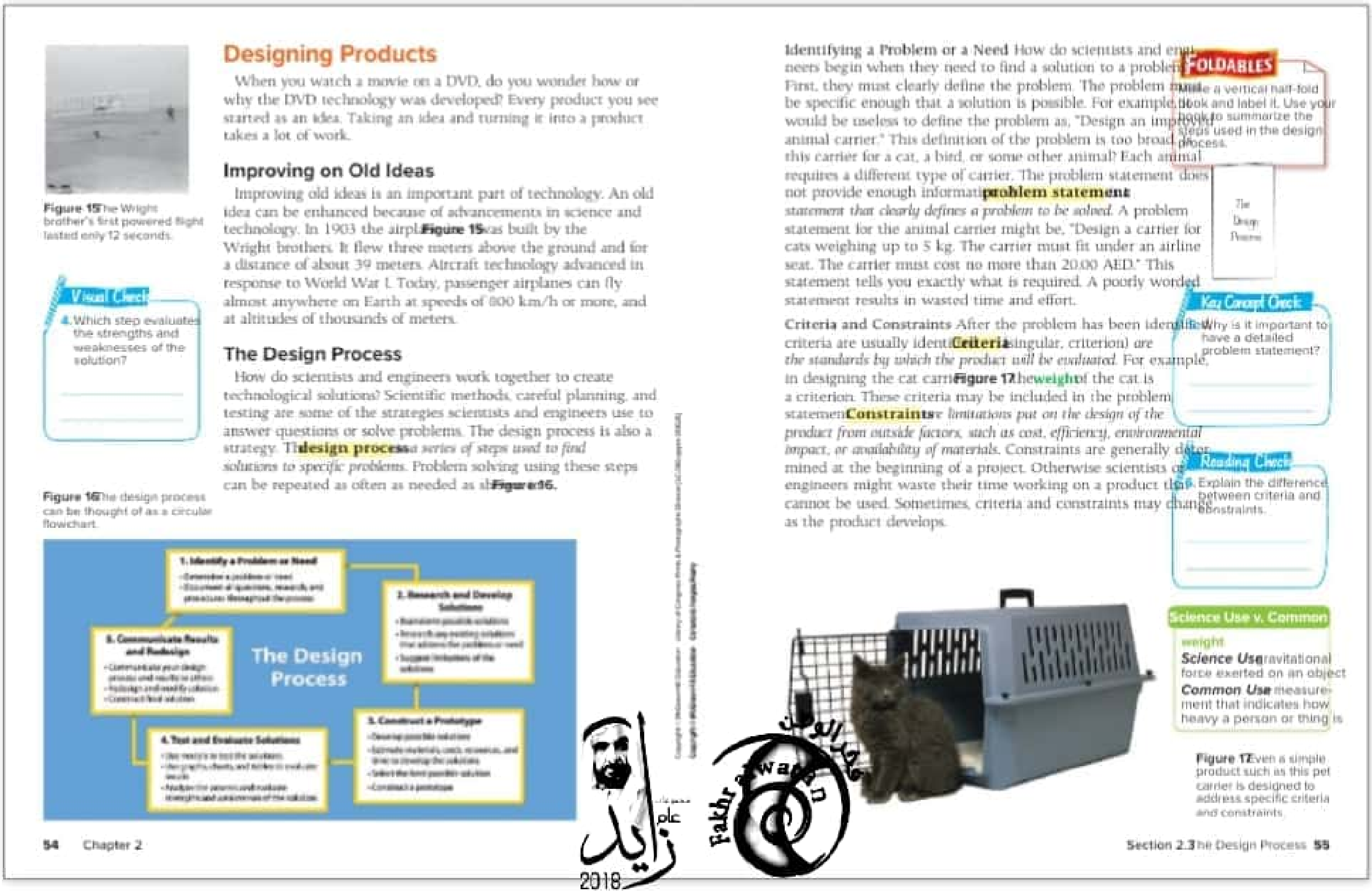
Reading Check Why is creativity an important design factor?	*New products start with an idea from someone.*
BL How can creativity affect the design of a product?	*It can produce a design that is original and imaginative.*

The Role of Engineering

Explain to students that there are many types of engineers. Engineering careers include, but not limited to, chemical, aeronautical, civil, and electrical. Direct student attention to **Figure 14** and read the caption. Discuss how this product's design is different from standard keyboards. Have students read the paragraph and respond to the questions.

Guiding Questions

OL What three qualities do engineers strive for in the design of a new product?	*durability, reliability, and ease of maintenance*
BL Why might some consider ergonomics a positive design feature?	*Possible answer: Since it relates to the human body, it would be a more comfortable product to use.*



Designing Products

When you watch a movie on a DVD, do you wonder how or why the DVD technology was developed? Every product you see started as an idea. Taking an idea and turning it into a product takes a lot of work.

Improving on Old Ideas

Improving old ideas is an important part of technology. An old idea can be enhanced because of advancements in science and technology. In 1903 the airpl**Figure 15**was built by the Wright brothers. It flew three meters above the ground and for a distance of about 39 meters. Aircraft technology advanced in response to World War I. Today, passenger airplanes can fly almost anywhere on Earth at speeds of 800 km/h or more, and at altitudes of thousands of meters.

The Design Process

How do scientists and engineers work together to create technological solutions? Scientific methods, careful planning, and testing are some of the strategies scientists and engineers use to answer questions or solve problems. The design process is also a strategy. Th**design process***a series of steps used to find solutions to specific problems.* Problem solving using these steps can be repeated as often as needed as sh**Figure 16.**

Figure 15The Wright brother's first powered flight lasted only 12 seconds.

Visual Check
4. Which step evaluates the strengths and weaknesses of the solution?

Figure 16The design process can be thought of as a circular flowchart.

The Design Process
1. Identify a Problem or Need
2. Research and Develop Solutions
3. Construct a Prototype
4. Test and Evaluate Solutions
5. Communicate Results and Redesign

Identifying a Problem or a Need How do scientists and engi-neers begin when they need to find a solution to a problem? First, they must clearly define the problem. The problem must be specific enough that a solution is possible. For example, it would be useless to define the problem as, "Design an improved animal carrier." This definition of the problem is too broad. Is this carrier for a cat, a bird, or some other animal? Each animal requires a different type of carrier. The problem statement does not provide enough informati**problem statement** *statement that clearly defines a problem to be solved.* A problem statement for the animal carrier might be, "Design a carrier for cats weighing up to 5 kg. The carrier must fit under an airline seat. The carrier must cost no more than 20.00 AED." This statement tells you exactly what is required. A poorly worded statement results in wasted time and effort.

Criteria and Constraints After the problem has been identified, criteria are usually identi**Criteria**(singular, criterion) *are the standards by which the product will be evaluated.* For example, in designing the cat carri**Figure 17**the**weight**of the cat is a criterion. These criteria may be included in the problem statemen**Constraints***re limitations put on the design of the product from outside factors, such as cost, efficiency, environmental impact, or availability of materials.* Constraints are generally deter-mined at the beginning of a project. Otherwise scientists or engineers might waste their time working on a product that cannot be used. Sometimes, criteria and constraints may change as the product develops.

FOLDABLES
Make a vertical half-fold book and label it. Use your book to summarize the steps used in the design process.

Key Concept Check
Why is it important to have a detailed problem statement?

Reading Check
6. Explain the difference between criteria and constraints.

Science Use v. Common
weight
Science Use gravitational force exerted on an object
Common Use measurement that indicates how heavy a person or thing is

Figure 17Even a simple product such as this pet carrier is designed to address specific criteria and constraints.

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Designing Products

Emphasize that every product began with an idea, some which seemed impossible to achieve at the time, others to address a practical need.

Improving on Old Designs

Direct student attentio**Figure 15**nd read the caption. Have students read the paragraph. Discuss how one idea can impact the future in ways not imagined at the time.

Guiding Questions

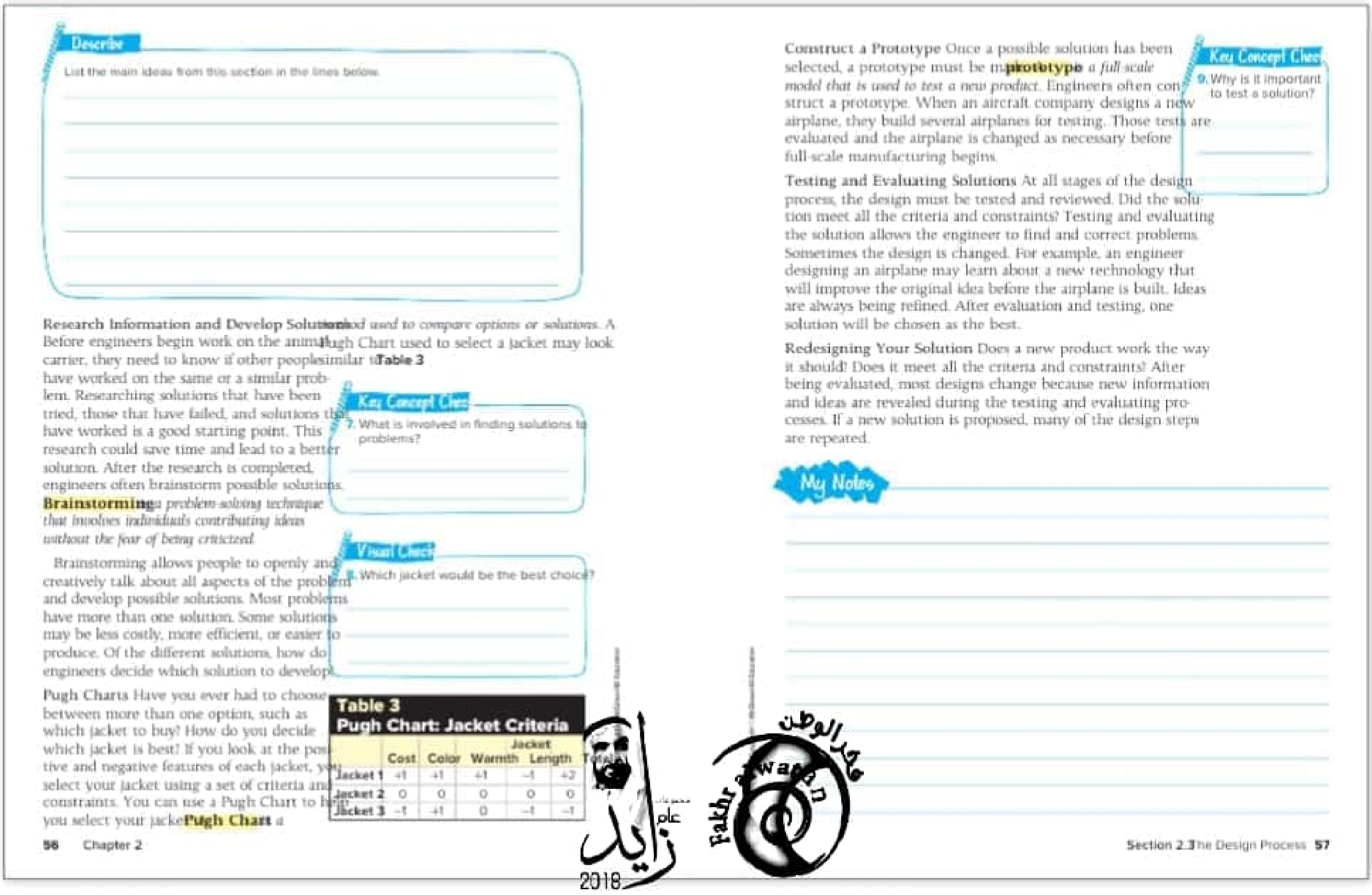
AL	Why is improving on old ideas an important part of technology?	*Possible answers: It's always good to find better ways to accomplish tasks. Improvements can save money, resources, time and reduce long-term impacts on health and/or environment.*
OL	Why can old ideas be improved?	*Old ideas can be improved because advancements have been made in science and technology.*

The Design Process

Have students read the paragraph. Draw atte**Figure 16**. Read through and discuss each step in the design process.

Guiding Questions

AL	What is the design process?	*a series of steps used to find solutions to specific problems*
OL	What are some of the tools that scientists and engineers use to create solutions?	*scientific method, planning, testing, design process*
	Visual Check Which step evaluates the strengths and weaknesses of the solution?	*Step 4—Test and Evaluate Solutions*



Describe

List the main ideas from this section in the lines below.

Research Information and Develop Solutions Before engineers begin work on the animal carrier, they need to know if other people have worked on the same or a similar problem. Researching solutions that have been tried, those that have failed, and solutions that have worked is a good starting point. This research could save time and lead to a better solution. After the research is completed, engineers often brainstorm possible solutions. **Brainstorming** *a problem-solving technique that involves individuals contributing ideas without the fear of being criticized.*

Brainstorming allows people to openly and creatively talk about all aspects of the problem and develop possible solutions. Most problems have more than one solution. Some solutions may be less costly, more efficient, or easier to produce. Of the different solutions, how do engineers decide which solution to develop?

Pugh Charts Have you ever had to choose between more than one option, such as which jacket to buy? How do you decide which jacket is best? If you look at the positive and negative features of each jacket, you select your jacket using a set of criteria and constraints. You can use a Pugh Chart to help you select your jacket. **Pugh Chart** *a method used to compare options or solutions.* A Pugh Chart used to select a jacket may look similar to **Table 3**.

Key Concept Check

7. What is involved in finding solutions to problems?

Visual Check

8. Which jacket would be the best choice?

Table 3
Pugh Chart: Jacket Criteria

Jacket	Cost	Color	Warmth	Length	Total
Jacket 1	+1	+1	+1	–1	+2
Jacket 2	0	0	0	0	0
Jacket 3	–1	+1	0	–1	–1

56 Chapter 2

Construct a Prototype Once a possible solution has been selected, a prototype must be made. **prototype** *a full-scale model that is used to test a new product.* Engineers often construct a prototype. When an aircraft company designs a new airplane, they build several airplanes for testing. Those tests are evaluated and the airplane is changed as necessary before full-scale manufacturing begins.

Testing and Evaluating Solutions At all stages of the design process, the design must be tested and reviewed. Did the solution meet all the criteria and constraints? Testing and evaluating the solution allows the engineer to find and correct problems. Sometimes the design is changed. For example, an engineer designing an airplane may learn about a new technology that will improve the original idea before the airplane is built. Ideas are always being refined. After evaluation and testing, one solution will be chosen as the best.

Redesigning Your Solution Does a new product work the way it should? Does it meet all the criteria and constraints? After being evaluated, most designs change because new information and ideas are revealed during the testing and evaluating processes. If a new solution is proposed, many of the design steps are repeated.

Key Concept Check

9. Why is it important to test a solution?

My Notes

Section 2.3 The Design Process 57

Research Information and Develop Solutions

Have students read to find out why it is important to research solutions to an identified problem. Discuss how brainstorming helps to facilitate problem-solving.

Guiding Questions

Key Concept Check What is involved in finding solutions to problems?	*collecting information on solutions to similar problems, original thought and creativity*
OL **Which jacket would be the best choice?**	*jacket 1*
Visual Check Answer:	*jacket 1*

Construct a Prototype

Read the definition for prototype and discuss the importance of having prototypes. Remind students that prototypes are physical models. Have students read the text and guide their understanding using the following questions.

Guiding Questions

AL **What is a prototype?**	*a full-scale model that is used to test a new product*
OL **Why is it important to build a prototype?**	*Building a prototype will give the engineers opportunity to change the product before full-scale production.*

Testing and Evaluating Solutions

Remind students that testing and evaluating are step 4 of the design process. Have students read the text. Discuss the importance of prototype testing. Assess student understanding of the concept by asking the following questions.

Guiding Questions

Key Concept Check Why is it important to test a solution?	*Testing a solution allows the engineer to find and correct problems with the design.*
BL **Why does having a consistent testing procedure improve the quality and cost of a product?**	*Consistent testing procedure reduces the amount of time production has to remake a new product.*

Key Concept Check
10. What are the steps of the design process?

Communicate Results Once the testing and the evaluations are completed, the results must be communicated. Scientists and engineers write reports and produce presentations for other scientists, engineers, government agencies, private industries, and the public. The reports provide details of the design process, summaries of the data, and final conclusions. Scientists and engineers include recommendations for further research in their reports. Scientists and engineers usually publish their most important findings. By communicating their results, other scientists or engineers have the opportunity to duplicate the work or to continue the work of others.

Full-Scale Production Once all of the problems in the design are resolved, manufacturing facilities, such as the one shown in **Figure 18**, may be created to manufacture the new product. The proposed product has undergone careful evaluation and testing, but the evaluation process does not stop when full-scale production begins. The materials that are used to make the product must be tested throughout the manufacturing process to assure that a quality product is produced.

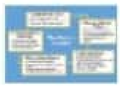
Figure 18 A product, such as this jumbo jet, is manufactured in quantity only after its entire design process is completed.

58 Chapter 2

SECTION 2.3 Review

Visualize It!

The design of new products begins with an idea. Engineers take ideas and turn them into products.



The design process is a series of steps used to find solutions to problems. Prototypes are often used to test solutions.

Summarize it!

1. What is the design process?

2. How can different solutions be tested and compared?

Section 2.3 The Design Process 59

Communicate Results

Have students read the text. Have students identify what information might be shared when communicating results. Use the following questions to guide understanding.

Guiding Questions

AL What step comes after a design solution meets all criteria and constraints tests?	*The results are communicated to other scientists and engineers.*
OL What tasks are included in communicating results?	*writing reports and producing presentations for others*
BL Why is communicating results an essential part of the design process?	*Communicating results allows other scientists to replicate and possibly improve on the original work.*

Full-Scale Production

Direct attention to **Figure 18** and read the caption. Review the steps taken in the design process before full-scale production occurs. Have students read the text and answer the questions.

Guiding Questions

AL When does full-scale production begin?	*after all problems in a design have been resolved*

Key Concept Check What are the steps of the design process?	*The steps include defining the problem, collecting information, developing possible solutions, building a model, testing the solution, evaluating the solution, redesigning the solution and communicating results.*
BL Why is it important to continue the evaluation process after full-scale production begins?	*It is important to ensure that materials used in production continually meet established standards and the product functions as intended over longer periods of time.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask:** **Which Key Concept does each image relate to?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Physical Properties
- Mechanical Properties
- Types of Materials

The Design Process

Use Vocabulary

1. **Define** *brainstorming* in your own words.
2. A method used to compare options or solutions is a ________.
3. **Use the term** *prototype* in a sentence.

Understand Key Concepts

4. **Explain** the influence engineering has on a design.
5. Which step in the design process has the engineer building a model for testing?
   - A. identify a problem
   - B. test a solution
   - C. construct a prototype
   - D. redesign a solution
6. **Arrange** Solve the problem of a river flooding annually by putting the following steps in order: a) investigating the river's source and its geography; b) build a model dam; c) create several designs of dams; d) write a problem statement; e) test the model; f) select the most promising dam design; g) redesign the model.

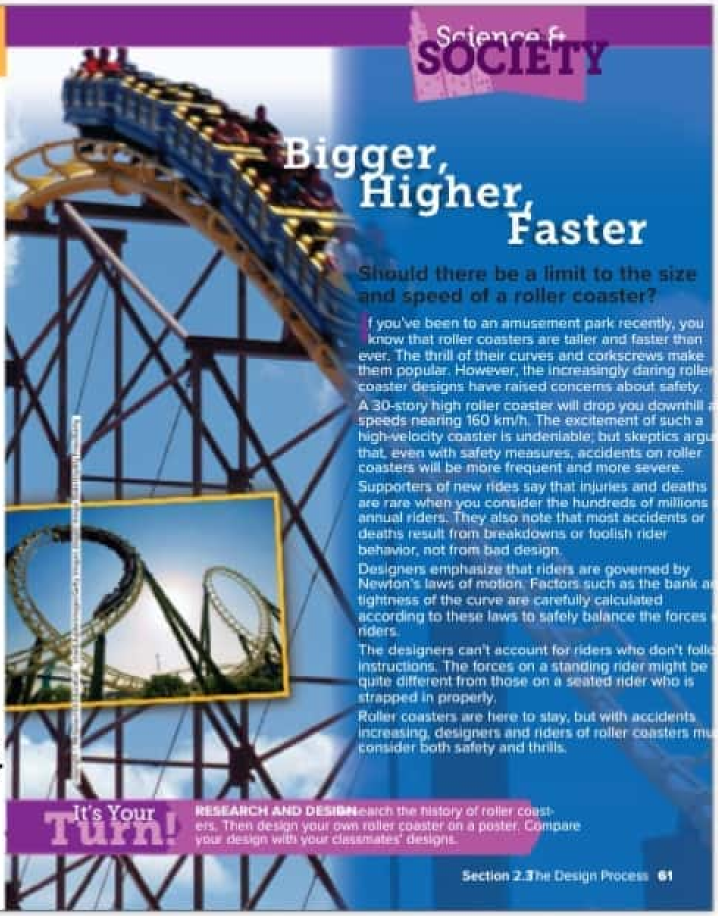
Interpret Graphics

7. **Organize Information** Copy and fill in the graphic organizer below to list the steps in the design process.

The Design Process → Define the Problem

Critical Thinking

8. **Explain** Why does the design process have so many steps?



Science & SOCIETY

Bigger, Higher, Faster

Should there be a limit to the size and speed of a roller coaster?

If you've been to an amusement park recently, you know that roller coasters are taller and faster than ever. The thrill of their curves and corkscrews make them popular. However, the increasingly daring roller coaster designs have raised concerns about safety.

A 30-story high roller coaster will drop you downhill a speeds nearing 160 km/h. The excitement of such a high-velocity coaster is undeniable; but skeptics argu that, even with safety measures, accidents on roller coasters will be more frequent and more severe.

Supporters of new rides say that injuries and deaths are rare when you consider the hundreds of millions annual riders. They also note that most accidents or deaths result from breakdowns or foolish rider behavior, not from bad design.

Designers emphasize that riders are governed by Newton's laws of motion. Factors such as the bank a tightness of the curve are carefully calculated according to these laws to safely balance the forces riders.

The designers can't account for riders who don't follo instructions. The forces on a standing rider might be quite different from those on a seated rider who is strapped in properly.

Roller coasters are here to stay, but with accidents increasing, designers and riders of roller coasters mu consider both safety and thrills.

It's Your Turn! RESEARCH AND DESIGN Research the history of roller coasters. Then design your own roller coaster on a poster. Compare your design with your classmates' designs.

Use Vocabulary

1. Possible answer: The design process is a series of steps used to find solutions to problems. **DOK 1**
2. Pugh Chart **DOK 1**
3. Possible answer: A prototype is a model of a new product used for testing. **DOK 2**

Understand Key Concepts

4. Engineering makes sure the product works well, is durable and reliable, and easy to maintain. **DOK 2**
5. C. construct a prototype **DOK 2**
6. d, a, c, f, b, e, g **DOK 3**

Interpret Graphics

7. Research information; Develop possible solutions; Build a prototype; Test and evaluate solutions; Redesign your solution; and communicate results **DOK 3**

Critical Thinking

8. The design process requires taking a specific series of steps to get the job done. The steps in the process might change, depending on the project. Building a new product from scratch, for example, would require more steps than improving on an already existing product. **DOK 4**

Science and SOCIETY

Bigger, Higher, Faster

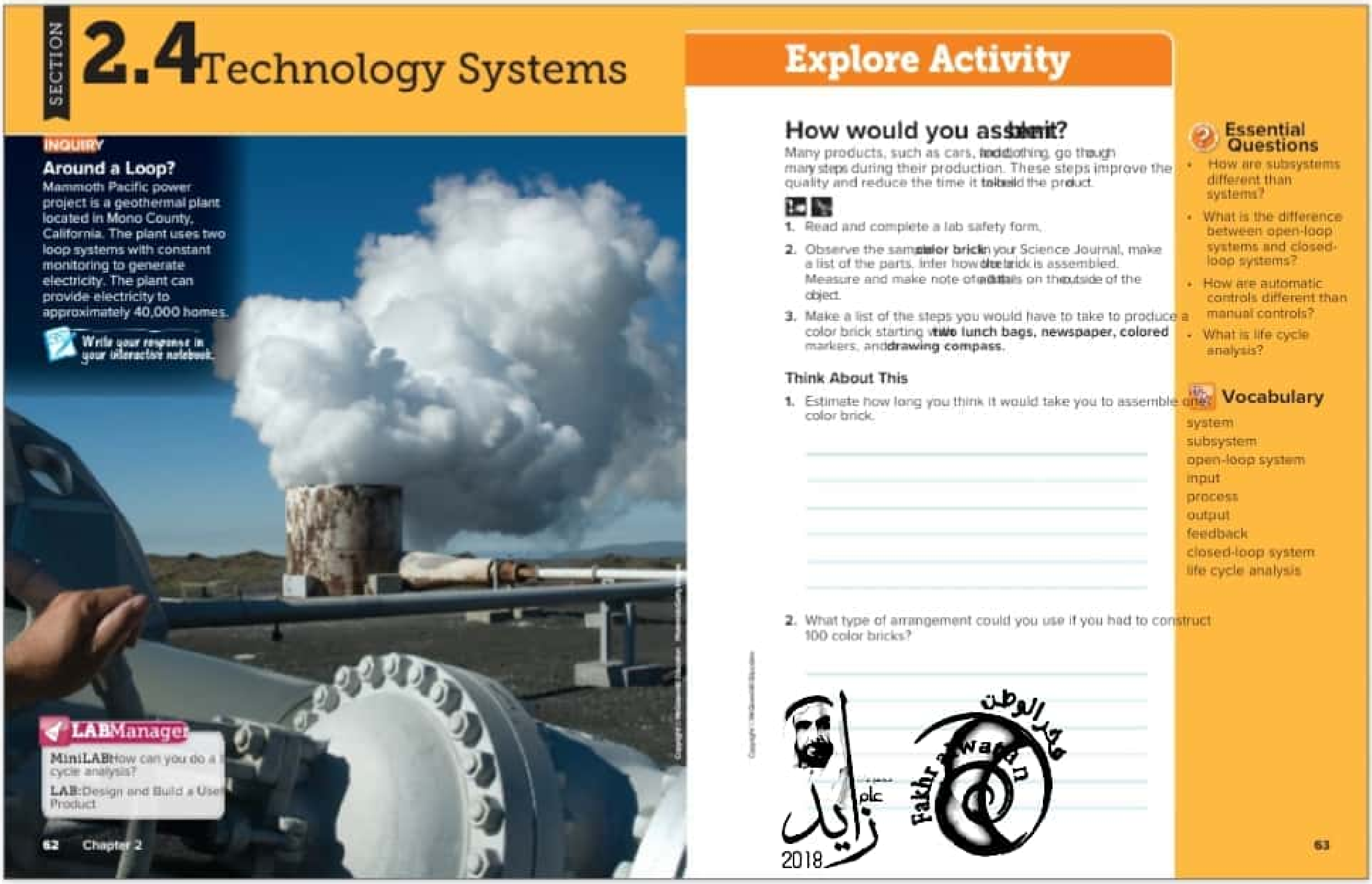
Background Information

Roller coasters originated in 15th century Russia in the form of iced chutes that were navigated on a block of ice with a straw seat. The first true roller coaster was built in St. Petersburg in 1784, and "Russian Mountains" appeared in Paris in 1804. Safety was not a concern. Injuries seemed to be more an enticement than a deterrent to riding them.

One of the first American coasters was a coalmine railway in Pennsylvania. People discovered that the fast downhill ride was exciting and would pay to ride it after the morning coal runs were finished.

The great roller coaster era began at the end of the 1800s when trolley companies started to build amusement parks at the end of their rail lines to attract customers on the weekends. The first roller coasters were low-speed gravity railways.

Thrill rides like Coney Islands' Flip-Flap and the Loop-the-Loop actually took riders through a 360-degree vertical loop. They were uncomfortable and dangerous but extremely popular until today's high speed coasters replaced them. Space Age engineering and Disneyland launched the modern coaster era. Tubular steel structure and nylon wheels made true looping coasters possible. The only limit to modern coaster design is the ability of the human body to endure G forces.



SECTION 2.4 Technology Systems

INQUIRY

Around a Loop? Mammoth Pacific power project is a geothermal plant located in Mono County, California. The plant uses two loop systems with constant monitoring to generate electricity. The plant can provide electricity to approximately 40,000 homes.

Write your response in your interactive notebook.

LABManager

MiniLAB: How can you do a life cycle analysis?

LAB: Design and Build a User Product

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Explore Activity

How would you assemble it?

Many products, such as cars, food, clothing, go through many steps during their production. These steps improve the quality and reduce the time it takes to build the product.

1. Read and complete a lab safety form.
2. Observe the sample **color brick**. In your Science Journal, make a list of the parts. Infer how the brick is assembled. Measure and make note of all details on the outside of the object.
3. Make a list of the steps you would have to take to produce a color brick starting with **two lunch bags, newspaper, colored markers,** and **drawing compass.**

Think About This

1. Estimate how long you think it would take you to assemble one color brick.
2. What type of arrangement could you use if you had to construct 100 color bricks?

Essential Questions

- How are subsystems different than systems?
- What is the difference between open-loop systems and closed-loop systems?
- How are automatic controls different than manual controls?
- What is life cycle analysis?

Vocabulary

system
subsystem
open-loop system
input
process
output
feedback
closed-loop system
life cycle analysis

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INQUIRY

About the Photo **Around the Loop?** The Mammoth Pacific power project is a geothermal power plant that converts thermal energy held in underground water reservoirs to electrical energy.

Guiding Questions

AL What is meant by *around a loop?*	*something that begins at one point, goes around, and ends at the same place*
OL What do you think goes around the loop at the power plant?	*water*
BL What is the purpose of the loop system?	*to convert the water's energy into electricity*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Visualization

Words become easier to recall and remember if a visual image can be attached to the meaning of the word.

1. Write the word *feedback* on the board or chart paper. **Ask: What two words do you find in the word feedback?** *feed* and *back*. Feedback is something that is given back after information is considered. **Ask: How does the word "feed" in this term compare to "feed" as in food?** Possible answer: *Both uses mean to give something. In science it is a response to give information. With food, it is the act of giving food to a living thing.*
2. Write *input* and *output* on the board. **Look at the words *input* and *output*. What am I asking for when I ask for your input on a project?** Possible Answer: *help or to share ideas with the project* **What do I mean when I say we need a lot of output today?** Possible answer: *a lot of work has to be done.* Encourage students to make pictures of words in their minds to help remember and understand word meanings.

Explore Activity

How would you assemble it?

Prep: *20 min* **Class:** *15 min*

Purpose
To have students think about systems and subsystems, which produce a product.

Materials per team
a color brick

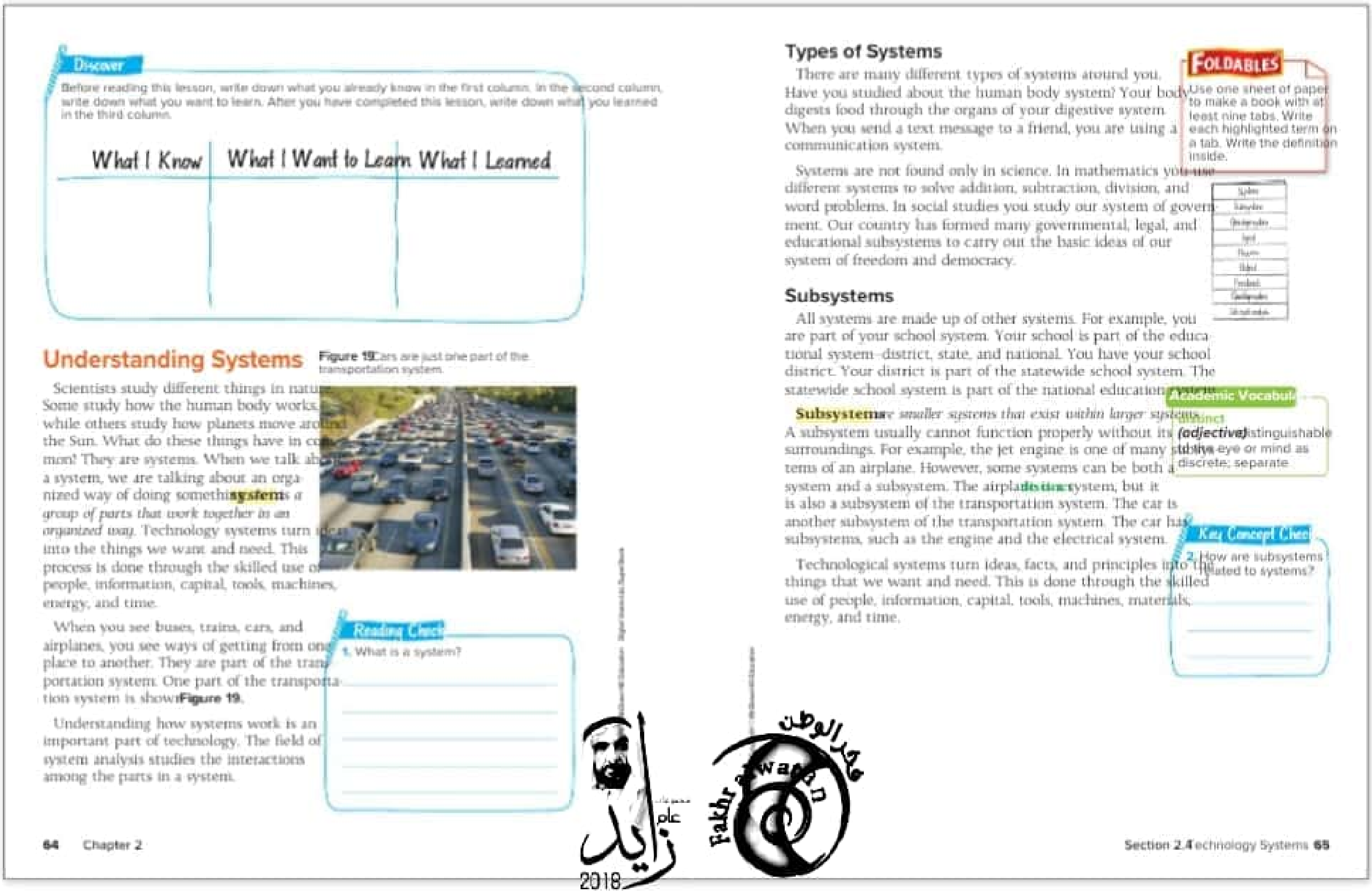
Alternative: You may assign larger teams so that you only need to make a couple of color bricks, or have students help you make samples.

Before You Begin
Prepare a sample color block for each team. Draw three one-inch circles and three two-inch circles on the flat sides of a paper lunch bag. Color the circles in four different colors (red, blue, yellow, and green). Draw five half-inch wide lines on the bottom of the bag. Fill a second bag with crushed newspaper. Insert the open end of that bag into the colored bag to form a brick.

Guide the Investigation
- Encourage students to draw the color brick first. Have them turn it around and specifically describe what is on each surface.
- Allow students to take the brick apart to see how it is constructed. Then have the students reassemble the brick.
- Have students think about the order in which they would produce a color brick. Then have students list the exact steps they would take.

Think About This
1. Students should guess at least 15 minutes. Share with students how long it took you to construct the samples.
2. **Key Concept** Answers will vary, but students should say that it would be easier if one person did each of the tasks, such as drawing the circles the right size, filling the circles with color, drawing the lines, filling the bag with newspaper, and assembling the two bags together.

Teacher Notes



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Understanding Systems

Figure 19 Cars are just one part of the transportation system.

Scientists study different things in nature. Some study how the human body works, while others study how planets move around the Sun. What do these things have in common? They are systems. When we talk about a system, we are talking about an organized way of doing something. A **system** is *a group of parts that work together in an organized way.* Technology systems turn ideas into the things we want and need. This process is done through the skilled use of people, information, capital, tools, machines, energy, and time.

When you see buses, trains, cars, and airplanes, you see ways of getting from one place to another. They are part of the transportation system. One part of the transportation system is shown in **Figure 19**.

Understanding how systems work is an important part of technology. The field of system analysis studies the interactions among the parts in a system.

Reading Check

1. What is a system?

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Types of Systems

There are many different types of systems around you. Have you studied about the human body system? Your body digests food through the organs of your digestive system. When you send a text message to a friend, you are using a communication system.

Systems are not found only in science. In mathematics you use different systems to solve addition, subtraction, division, and word problems. In social studies you study our system of government. Our country has formed many governmental, legal, and educational subsystems to carry out the basic ideas of our system of freedom and democracy.

FOLDABLES Use one sheet of paper to make a book with at least nine tabs. Write each highlighted term on a tab. Write the definition inside.

Subsystems

All systems are made up of other systems. For example, you are part of your school system. Your school is part of the educational system–district, state, and national. You have your school district. Your district is part of the statewide school system. The statewide school system is part of the national education system.

Subsystems are *smaller systems that exist within larger systems.* A subsystem usually cannot function properly without its surroundings. For example, the jet engine is one of many subsystems of an airplane. However, some systems can be both a system and a subsystem. The airplane is a **distinct** system, but it is also a subsystem of the transportation system. The car is another subsystem of the transportation system. The car has subsystems, such as the engine and the electrical system.

Academic Vocabulary

distinct *(adjective)* distinguishable to the eye or mind as discrete; separate

Technological systems turn ideas, facts, and principles into the things that we want and need. This is done through the skilled use of people, information, capital, tools, machines, materials, energy, and time.

Key Concept Check

2. How are subsystems related to systems?

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Understanding Systems

Write the term *system* on the board or chart paper and read its definition. Have students read the three paragraphs and answer the questions. Direct student attention to **Figure 19** and read the caption. Have students speculate on the parts that make up the transportation system.

Guiding Questions

AL	What does a technology system do?	*turns ideas into the things we want and need*
	Reading Check What is a system?	*collection of structures, cycles, and process that relate to and interact with each other*
BL	What is the field of systems analysis?	*The field of system analysis studies the interactions among the parts of a system.*

Types of Systems

Point out that there are many different types of systems. Ask students to explain how a system works in sports—a football play, for example, or soccer players moving the ball down the field to make a goal. Have students read the paragraphs and then ask the following questions.

Guiding Questions

AL	What is an example of a system?	*Possible answers: mathematics, human body*
OL	How is a text message part of a communication system?	*Possible answer: It makes a connection between two points. It travels through a system of wireless technology.*
BL	In what way is the federal government a system?	*Possible answer: Several different individuals, departments, and branches of government work together to accomplish established goals.*

Diagramming Systems

Why do people use diagrams when they make plans? Soccer coaches often diagram plays to help team members understand what they are going to do during a game. Technology uses a method of diagramming, originally developed by engineers, to help people understand how a system operates. A diagram shows how one part of a system relates to the other parts. This same diagram can also help people organize plans for new ideas. Two systems that can be diagrammed are open-loop systems and closed-loop systems.

Key Concept Check
3. Why is diagramming systems helpful?

Open-Loop Systems

Have you ever seen an irrigation sprinkler, such as the one shown in **Figure 20**, watering the grass while it rained? The sprinkler operates at set times, even when it is raining. The only way to turn the sprinkler off is for a person to do it. *When a system has no way to measure or control its product, the system is called an* **open-loop system**. Bathtubs, stoves, and traffic lights are examples of open-loop systems. What makes them open-loop systems? What is not being controlled?

These devices cannot operate without human input. Water in bathtub might overflow unless a person turns off the water. A stove will continue to heat and may burn food. A red traffic light automatically goes on even when there is no cross traffic. A person must control these systems.

An open-loop system includes three parts: input, process, and output. **Input** *is the resources, ideas, and activities that determine what needs to be accomplished.* For example, you might want to run for school president. You decide to make campaign posters and buttons. All the steps that lead up to the idea of creating these posters and buttons are part of the input.

Figure 20 A sprinkler system is an example of an open-loop system. The sprinkler will continue to operate until someone turns it off.

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Open-Loop Process

After deciding to make campaign materials, the next step in the open-loop system is to make your buttons and posters. The creation and making of a product is a process. A **process** *is the conversion of ideas or activities into products by using machines and labor.* Designing your buttons and posters and determining the steps involved in making them also are part of the process shown in **Figure 21**. Different products and different technologies involve different processes.

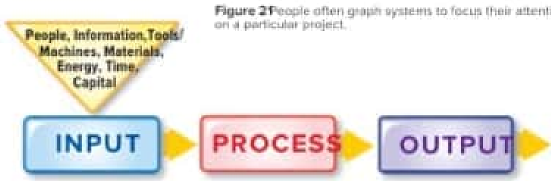
Output *is what the system produces.* Your posters and buttons would be the output of your campaign planning. The three parts of an open-loop system are an idea (input), which leads to an action (process), which leads to an outcome (output), as shown in **Figure 21**. Sometimes an output can become the input for another system.

Can an open-loop system measure effectiveness? Could you tell if your buttons and posters accurately communicated your message to the other students? Probably not. How could you measure the effectiveness of your buttons and posters?

Key Concept Check
4. What is a process?

Visual Check
5. If you were making buttons for your school team, what information would you place in each section of your open-looped system?

Figure 21 People often graph systems to focus their attention on a particular project.



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Diagramming Systems

Emphasize that a diagram shows how one part of a system relates to the other parts. On the board or chart paper, diagram how children are part of a family who are part of a larger family that is part of an extended family. Use the following questions to gauge students' understanding.

Guiding Questions

AL What does a diagram show?	*A diagram shows how one part of a system relates to the other parts.*
Key Concept Check Why is diagramming systems helpful?	*It shows how the various parts relate to one another.*
BL How does Earth and the living and non-living things on it relate to the system concept?	*Possible answer: Everything on Earth makes one planetary system. The planet is made up of many sub-systems, such as the ocean and land. On those systems, other smaller systems function, such as an ecosystem. The layers of systems keep going, which shows everything on Earth is connected.*

Open-Loop Systems

Write *open-loop system* on the board and read its definition. Have students read the three paragraphs. Then, direct student attention to **Figure 20** and read the caption. Assess student understanding by asking the following questions.

Guiding Questions

AL What three parts make up an open-loop system?	*input, process, and output*
OL What is an open-loop system?	*a system that has no way to measure or control its product*
BL What role do people have in an open-loop system?	*People control the system.*

Key Concept Check Answer A process is the conversion of ideas or activities into products by using machines and labor.

Open-Loop Process

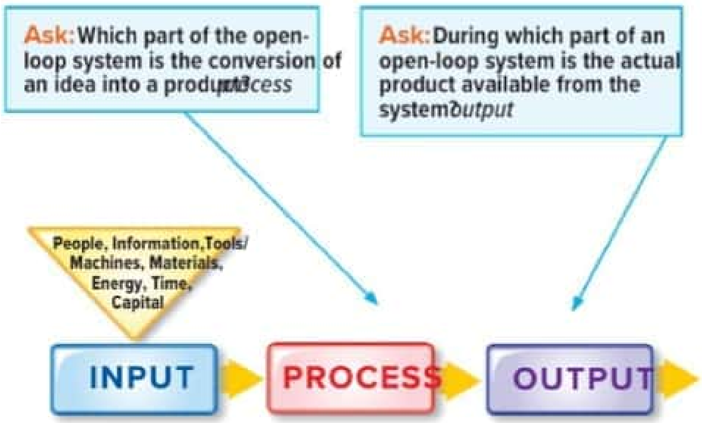
Have students read the text, followed by asking the first guiding question. Help students understand how different products and different technologies involve different processes. Assess student understanding by asking the remaining two questions.

Guiding Questions

OL What is a process?	conversion of ideas or activities into products by using machines and labor
Visual Check: If you were making buttons for your school team, what information would you place in each section of your open-looped system?	*Input:* pictures, slogan, paints and brushes or paste, blank buttons. *Process:* paint or paste picture and slogan on each button. *Output:* completed buttons to distribute.
BL When might an output become the input for another system?	Possible answer: when the output from one system becomes an idea or component for another system. For example, a hen laying eggs and the egg as an ingredient in a recipe.

Visual Literacy: Open-Loop Systems

Use **Figure 27** and the questions below to help students think about open-loop systems.



Differentiated Instruction

AL **Open-Loop Systems** Divide students into small groups. Provide chart paper and markers for each group. Assign one of the following topics to each group: water system, home entertainment systems, home appliances, vehicle, and personal banking system. Each group should use the markers to create an input–process–output diagram to explain its assigned open-loop system. Display chart pa

BL **Creating a Closed-Loop System** Form groups of five students with each group identifying a closed-loop syst Have the group illustrate how the system uses feedbac control the outcome of the system. Have each group sh their illustration and explanation.

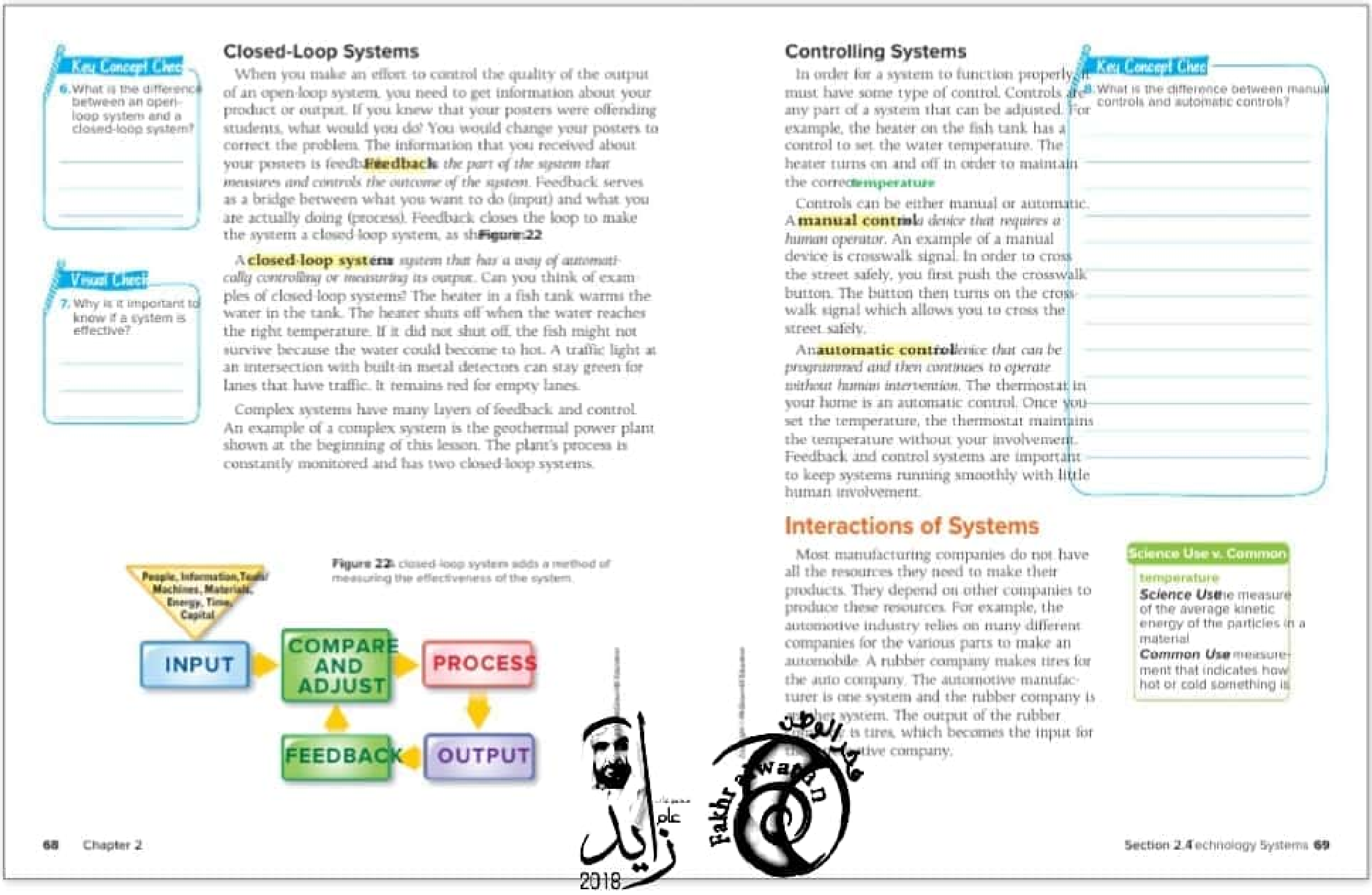
Teacher Toolbox

Fun Fact

Telephone Operators Today our communication systems are closed-loop systems. Feedback provides callers wit call waiting, call forwarding, and voice mail. In the early 1900s an open-loop system controlled phone connectio Operators managed a switchboard containing some 20 phone lines. The operators worked first by answering and then plugging an incoming call into the phone line the person being called. As phone service grew, city operators handled as many as 600 calls an hour.

Reading Strategy

Summarizing Have students write a summary of an open-loop system and a summary of a closed-loop syst Form student pairs. Have them compare their summar and add illustrations to their written work.



Closed-Loop Systems

When you make an effort to control the quality of the output of an open-loop system, you need to get information about your product or output. If you knew that your posters were offending students, what would you do? You would change your posters to correct the problem. The information that you received about your posters is feedback. **Feedback** is *the part of the system that measures and controls the outcome of the system*. Feedback serves as a bridge between what you want to do (input) and what you are actually doing (process). Feedback closes the loop to make the system a closed-loop system, as shown in **Figure 22**.

A **closed-loop system** is a *system that has a way of automatically controlling or measuring its output*. Can you think of examples of closed-loop systems? The heater in a fish tank warms the water in the tank. The heater shuts off when the water reaches the right temperature. If it did not shut off, the fish might not survive because the water could become to hot. A traffic light at an intersection with built-in metal detectors can stay green for lanes that have traffic. It remains red for empty lanes.

Complex systems have many layers of feedback and control. An example of a complex system is the geothermal power plant shown at the beginning of this lesson. The plant's process is constantly monitored and has two closed-loop systems.

Key Concept Check
6. What is the difference between an open-loop system and a closed-loop system?

Visual Check
7. Why is it important to know if a system is effective?

Figure 22 A closed-loop system adds a method of measuring the effectiveness of the system.

Controlling Systems

In order for a system to function properly, it must have some type of control. Controls are any part of a system that can be adjusted. For example, the heater on the fish tank has a control to set the water temperature. The heater turns on and off in order to maintain the correct temperature.

Controls can be either manual or automatic. A **manual control** is *a device that requires a human operator*. An example of a manual device is crosswalk signal. In order to cross the street safely, you first push the crosswalk button. The button then turns on the crosswalk signal which allows you to cross the street safely.

An **automatic control** is a *device that can be programmed and then continues to operate without human intervention*. The thermostat in your home is an automatic control. Once you set the temperature, the thermostat maintains the temperature without your involvement. Feedback and control systems are important to keep systems running smoothly with little human involvement.

Key Concept Check
8. What is the difference between manual controls and automatic controls?

Interactions of Systems

Most manufacturing companies do not have all the resources they need to make their products. They depend on other companies to produce these resources. For example, the automotive industry relies on many different companies for the various parts to make an automobile. A rubber company makes tires for the auto company. The automotive manufacturer is one system and the rubber company is another system. The output of the rubber company is tires, which becomes the input for the automotive company.

Science Use v. Common Use
temperature
Science Use the measure of the average kinetic energy of the particles in a material
Common Use measurement that indicates how hot or cold something is

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Closed-Loop Systems

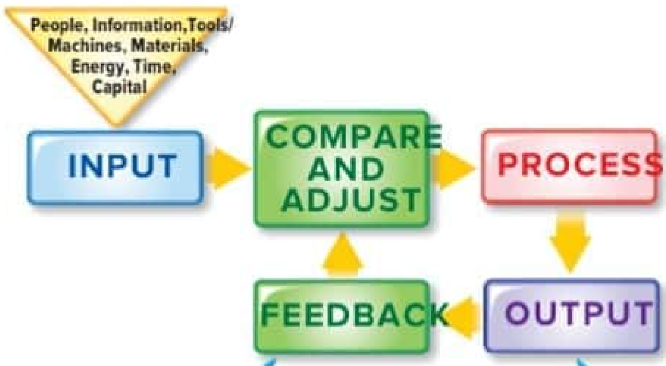
Have students read the text. Review the examples of closed-loop systems in the reading. Have students identify the control in each system. Emphasize that feedback controls the outcome of a closed-loop system. Use the guiding questions to assess student understanding.

Guiding Questions

AL What is feedback?	*the part of the system that measures and controls the outcome of the system*
Visual Check What is the difference between an open-loop system and a closed-loop system?	*The closed-loop system has feedback.*
Key Concept Check Why is it important to know if a system is effective?	*Only with feedback information can a product or system be fixed or improved.*

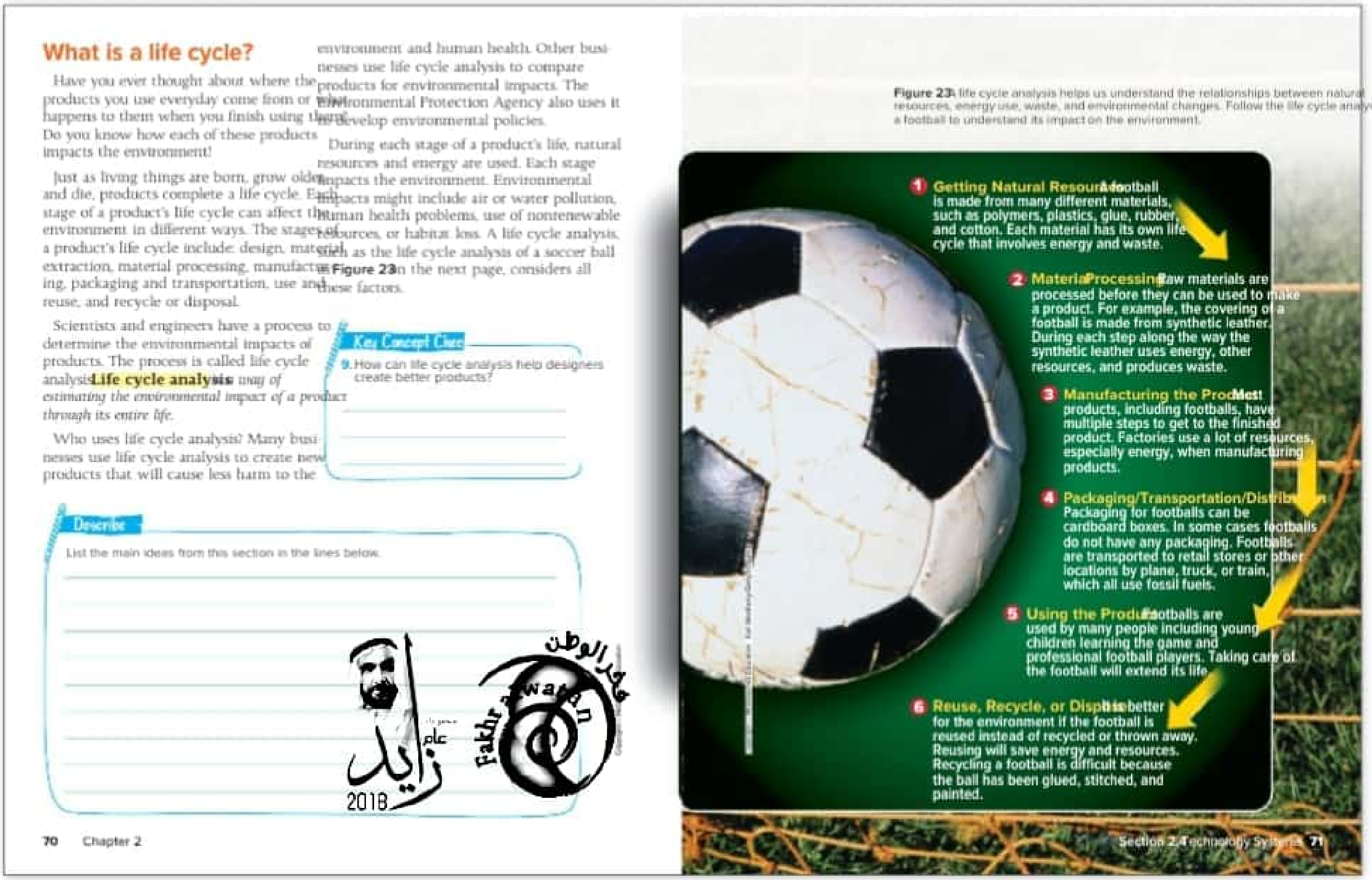
Visual Literacy: Closed-Loop Systems

Use **Figure 22** and the questions below to help students think about closed-loop systems.



Ask: Why is feedback important to a closed-loop system? *It measures and controls the outcome of the system.*

Ask: How is the output of a closed-loop system controlled? *It is automatically controlled by feedback.*



What is a life cycle?

Have you ever thought about where the products you use everyday come from or what happens to them when you finish using them? Do you know how each of these products impacts the environment?

Just as living things are born, grow older, and die, products complete a life cycle. Each stage of a product's life cycle can affect the environment in different ways. The stages of a product's life cycle include: design, material extraction, material processing, manufacturing, packaging and transportation, use and reuse, and recycle or disposal.

Scientists and engineers have a process to determine the environmental impacts of products. The process is called life cycle analysis. **Life cycle analysis** is *a way of estimating the environmental impact of a product through its entire life.*

Who uses life cycle analysis? Many businesses use life cycle analysis to create new products that will cause less harm to the environment and human health. Other businesses use life cycle analysis to compare products for environmental impacts. The Environmental Protection Agency also uses it to develop environmental policies.

During each stage of a product's life, natural resources and energy are used. Each stage impacts the environment. Environmental impacts might include air or water pollution, human health problems, use of nonrenewable resources, or habitat loss. A life cycle analysis, such as the life cycle analysis of a soccer ball in **Figure 23** on the next page, considers all these factors.

Key Concept Check

9. How can life cycle analysis help designers create better products?

Describe

List the main ideas from this section in the lines below.

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Figure 23 A life cycle analysis helps us understand the relationships between natural resources, energy use, waste, and environmental changes. Follow the life cycle analysis of a football to understand its impact on the environment.

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What is a life cycle?

Write *life cycle analysis* on the board and read its definition. Have students identify products that may impact the environment, such as empty water bottles or plastic bags. Have them read the section.

Guiding Questions

AL What is used in each stage of a product's life?	*natural resources and energy*
Key Concept Check How can life cycle analysis help designers create better products?	*Life cycle analysis can be used to reduce environmental impact, reduce the cost of production, and make it easier to maintain and repair.*
BL What might a life cycle analysis of a product indicate about the product's impact on the environment?	*Possible answer: It may cause air or water pollution, increase habitat loss, or adversely affect human health.*

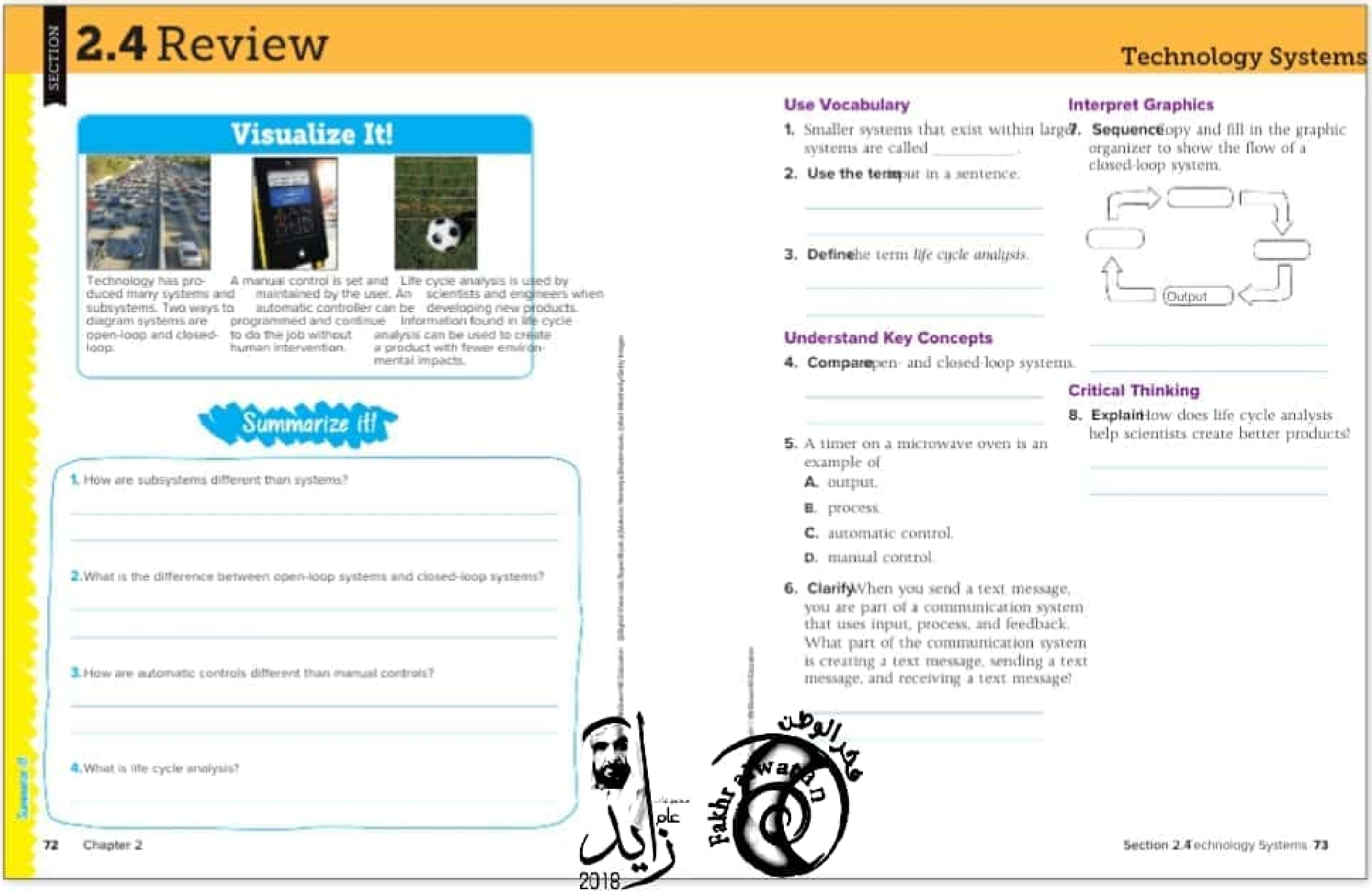
Describe Answer Student answers will vary.

The Life Cycle of a Soccer Ball

Review the definition of life cycle analysis. Read the caption and direct students to the six steps in the life cycle of a soccer ball. Have students read and discuss each step. Use the following questions to guide student understanding.

Guiding Questions

AL What resources are used to create a soccer ball?	*polymers, plastics, glue, rubber, cotton*
OL What is used to process the material that becomes a soccer ball? What is produced during the process	*Energy and other resources are used. Waste is produced.*
BL Why is it difficult to recycle a soccer ball?	*Several processes are used that result in the soccer ball being glued, stitched, and painted.*



SECTION **2.4 Review** Technology Systems

Visualize It!

Technology has produced many systems and subsystems. Two ways to diagram systems are open-loop and closed-loop.

A manual control is set and maintained by the user. An automatic controller can be programmed and continue to do the job without human intervention.

Life cycle analysis is used by scientists and engineers when developing new products. Information found in life cycle analysis can be used to create a product with fewer environmental impacts.

Summarize it!

1. How are subsystems different than systems?
2. What is the difference between open-loop systems and closed-loop systems?
3. How are automatic controls different than manual controls?
4. What is life cycle analysis?

Use Vocabulary

1. Smaller systems that exist within larger systems are called ______.
2. **Use the term** input in a sentence.
3. **Define** the term *life cycle analysis.*

Understand Key Concepts

4. **Compare** open- and closed-loop systems.
5. A timer on a microwave oven is an example of
 A. output.
 B. process.
 C. automatic control.
 D. manual control.
6. **Clarify** When you send a text message, you are part of a communication system that uses input, process, and feedback. What part of the communication system is creating a text message, sending a text message, and receiving a text message?

Interpret Graphics

7. **Sequence** Copy and fill in the graphic organizer to show the flow of a closed-loop system.

Output

Critical Thinking

8. **Explain** How does life cycle analysis help scientists create better products?

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Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which key concept does each image relate to?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Understanding Systems
- Diagramming Systems
- What is a Life Cycle

Use Vocabulary

1. subsystem **DOK 1**
2. Sample answer: Input can be the ideas, which is used at the beginning of a process. **DOK 2**
3. Life cycle analysis is a method of estimating the environmental impact of a product throughout its life. **DOK 1**

Understand Key Concepts

4. An open-loop system does not include a way to measure or control its product; it includes input, process, and output. A closed-loop system adds feedback about the end product. **DOK 2**
5. D. manual control **DOK 2**
6. Input-creating a text message; process-sending the text message; output-receiving the text message **DOK 3**

Interpret Graphics

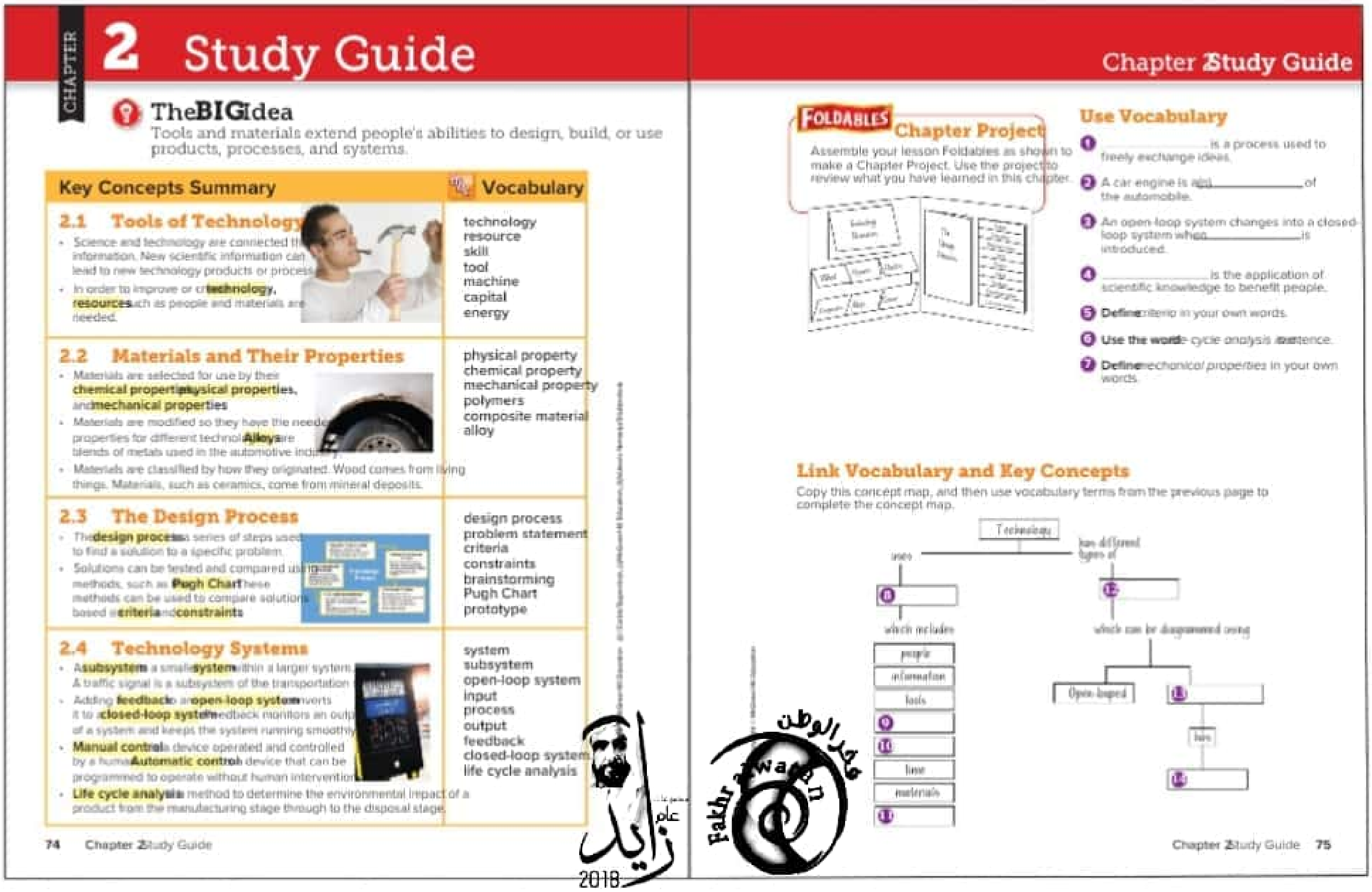
7. In a clockwise manner: input; process; feedback **DOK 2**

Critical Thinking

8. Life cycle analysis helps scientist by providing information on the resources and their environmental impact. **DOK 4**

LABManager

Design and Build a Useful Product This lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.


CHAPTER 2 Study Guide

The BIG Idea Tools and materials extend people's abilities to design, build, or use products, processes, and systems.

Key Concepts Summary	Vocabulary
2.1 Tools of Technology • Science and technology are connected through information. New scientific information can lead to new technology products or processes. • In order to improve or create **technology**, **resources** such as people and materials are needed.	technology, resource, skill, tool, machine, capital, energy
2.2 Materials and Their Properties • Materials are selected for use by their **chemical properties**, **physical properties**, and **mechanical properties**. • Materials are modified so they have the needed properties for different technologies. **Alloys** are blends of metals used in the automotive industry. • Materials are classified by how they originated. Wood comes from living things. Materials, such as ceramics, come from mineral deposits.	physical property, chemical property, mechanical property, polymers, composite material, alloy
2.3 The Design Process • The **design process** is a series of steps used to find a solution to a specific problem. • Solutions can be tested and compared using methods, such as a **Pugh Chart**. These methods can be used to compare solutions based on **criteria** and **constraints**.	design process, problem statement, criteria, constraints, brainstorming, Pugh Chart, prototype
2.4 Technology Systems • A **subsystem** is a smaller **system** within a larger system. A traffic signal is a subsystem of the transportation system. • Adding **feedback** to an **open-loop system** converts it to a **closed-loop system**. Feedback monitors an output of a system and keeps the system running smoothly. • **Manual control** is a device operated and controlled by a human. **Automatic control** is a device that can be programmed to operate without human intervention. • **Life cycle analysis** is a method to determine the environmental impact of a product from the manufacturing stage through to the disposal stage.	system, subsystem, open-loop system, input, process, output, feedback, closed-loop system, life cycle analysis

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Chapter 2 Study Guide

FOLDABLES Chapter Project Assemble your lesson Foldables as shown to make a Chapter Project. Use the project to review what you have learned in this chapter.

Use Vocabulary
1. ______ is a process used to freely exchange ideas.
2. A car engine is a(n) ______ of the automobile.
3. An open-loop system changes into a closed-loop system when ______ is introduced.
4. ______ is the application of scientific knowledge to benefit people.
5. Define criteria in your own words.
6. Use the words life cycle analysis in a sentence.
7. Define mechanical properties in your own words.

Link Vocabulary and Key Concepts
Copy this concept map, and then use vocabulary terms from the previous page to complete the concept map.

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Key Concepts Summary

Study Strategy: Metacognition

Metacognition allows students to engage in higher order critical thinking skills. To accomplish this, students pose questions to themselves about the material being studied.

1. Have students review Lesson 3 and write five Key Concept questions from Lesson 3.
2. Each student should then write a summary statement answering the Key Concept questions.
3. Encourage students who cannot write a complete answer to design a learning strategy for reviewing the information, such as creating a graphic organizer, reading the information aloud, or explaining it to another student.
4. Create student teams. Have students share their questions, responses, and strategies for effective learning.
5. Have selected students share one question, response, and strategy with the class.

Vocabulary

Study Strategy: Restating

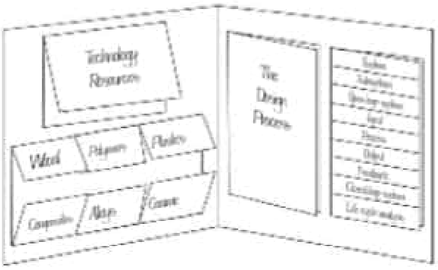
Restating words in the student's own vocabulary is an effective technique for vocabulary recall and comprehension. If there is time, have students work in pairs. One student selects a vocabulary word. The other student restates the meaning of the vocabulary word using his or hers own words. Then have the students switch roles.

1. Students should create a three-column chart like the own below in their Science Journals.
2. Have students write the chapter's vocabulary words in the left column.
3. Have students write the definition of the word in the center column.
4. Students should restate the word's definition in the right column.

Example:

Vocabulary Word	Definition	Restated Definition
technology	the application of scientific knowledge to benefit people	using science to create product designs that help people

FOLDABLES®



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

Teacher Notes

Use Vocabulary

1. Brainstorming
2. subsystem
3. feedback
4. Technology
5. Criteria are standards that a product will be evaluated on.
6. Life cycle analysis evaluates the environmental impact of a product through all stages of the product's life.
7. Mechanical properties are characteristics, such as strength and flexibility that determine how a material reacts to forces.

Link Vocabulary and Key Concepts

8. resources
9. machines
10. capital
11. energy
12. systems
13. closed-loop
14. feedback

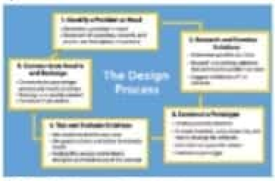
CHAPTER 2 Review

Chapter Review

Understand Key Concepts

1. Which technology resource is the source of power that runs technological systems?
   A. people C. energy
   B. tools D. capital
2. Which term provides information on how a product can reduce its environmental impact?
   A. open-loop system
   B. closed-loop system
   C. life cycle analysis
   D. Pugh Chart

Use the Design Process flowchart to answer questions 3 and 4.



3. In which step of the design process would a Pugh Chart be used?
   A. Step 1 C. Step 4
   B. Step 3 D. Step 5
4. What is the typical next step after building a prototype?
   A. brainstorming C. selling
   B. manufacturing D. testing
5. Multiplication is a subsystem of
   A. division. C. subtraction.
   B. mathematics. D. geography.
6. What is the normal flow of an open-loop system?
   A. input, process, output
   B. process, input, output
   C. input, feedback, process, output
   D. input, output, process, feedback
7. What type of material resource does the image below represent?

   A. manufactured materials
   B. processed materials
   C. raw materials
   D. synthetic materials
8. Which mechanical property determines a material's ability to resist bending?
   A. elasticity B. flexibility
   C. hardness D. strength
9. What part of a product's life cycle analysis is finding another use for the product?
   A. materials processing
   B. manufacturing the product
   C. using the product
   D. recycling of the product
10. In a large city, there are many ways to get around. There are buses, trains, and taxicabs. All of these are parts of the overall transportation system of the city. What do we call these smaller parts of the larger transportation system?
   A. system
   B. subsystem
   C. open-loop system
   D. closed-loop system
11. Which type of material does a doctor use to replace or repair broken bones?

   A. alloys C. composites
   B. ceramics D. polymers

12. What is one method to test and compare different solutions?
   A. brainstorming
   B. design process
   C. Pugh Chart
   D. problem statement

Critical Thinking

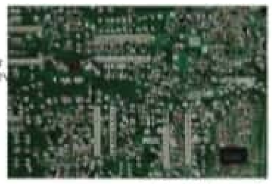
13. **Explain** why technologists must consider cost when they plan to manufacture a product.
14. **Compare** manual controls to automatic controls.
15. **Discuss** how materials are selected for a particular product.
16. **Explain** Why do people diagram plans?
17. **Determine** you test and adjust your solution, are you using an open-loop or closed-loop system?
18. **Give Example** one form of technology you frequently use. Describe how your ... uld be different if that technology nev... developed.
19. **Decide** Would you rather work as a scientist or as an engineer as a career? What personal strengths or weaknesses led you to you decision?
20. **Conceive** Brainstorm a new invention that would make your classroom a better place for students. List the materials that you would use to build your device. How did you select the materials for your device?

Writing in Science

21. **Create** flowchart to show the design process used to develop a skateboard.

TheBIGIdea

22. Describe how tools and materials are used to modify or create new technologies.
23. How do scientists and engineers select materials for a new product?



Understand Key Concepts

1 **C.** energy
2 **C.** life cycle analysis
3 **C.** Step 4.
4 **D.** testing
5 **B.** mathematics
6 **A.** input, process, output
7 **A.** manufactured materials
8 **B.** flexibility
9 **D.** recycling of the product
10 **B.** subsystem
11 **A.** alloys
12 **C.** Pugh Chart

Critical Thinking

13 They must ensure the cost to make a product is less than what it will sell for.
14 A manual control is a device that requires a user to operate. An automatic control is a device that can be programmed to operate without human intervention.
15 Materials are selected based on their physical, chemical, and mechanical properties.
16 It helps people organize what they plan to do. The diagram helps them see relationships that exist within their plan.
17 You are using a closed-loop system because you are using feedback to determine the need to adjust.
18 Answers will vary. A possible response could include comments about how the student could or could not compensate for the lack of the particular technology in his or her life.
19 Answers will vary. Responses could include comments about whether the particular student feels more comfortable working with ideas, or prefers to work hands-on solving problems.
20 Answers will vary. Responses should include comments about the advantages of various materials based on the materials' properties.

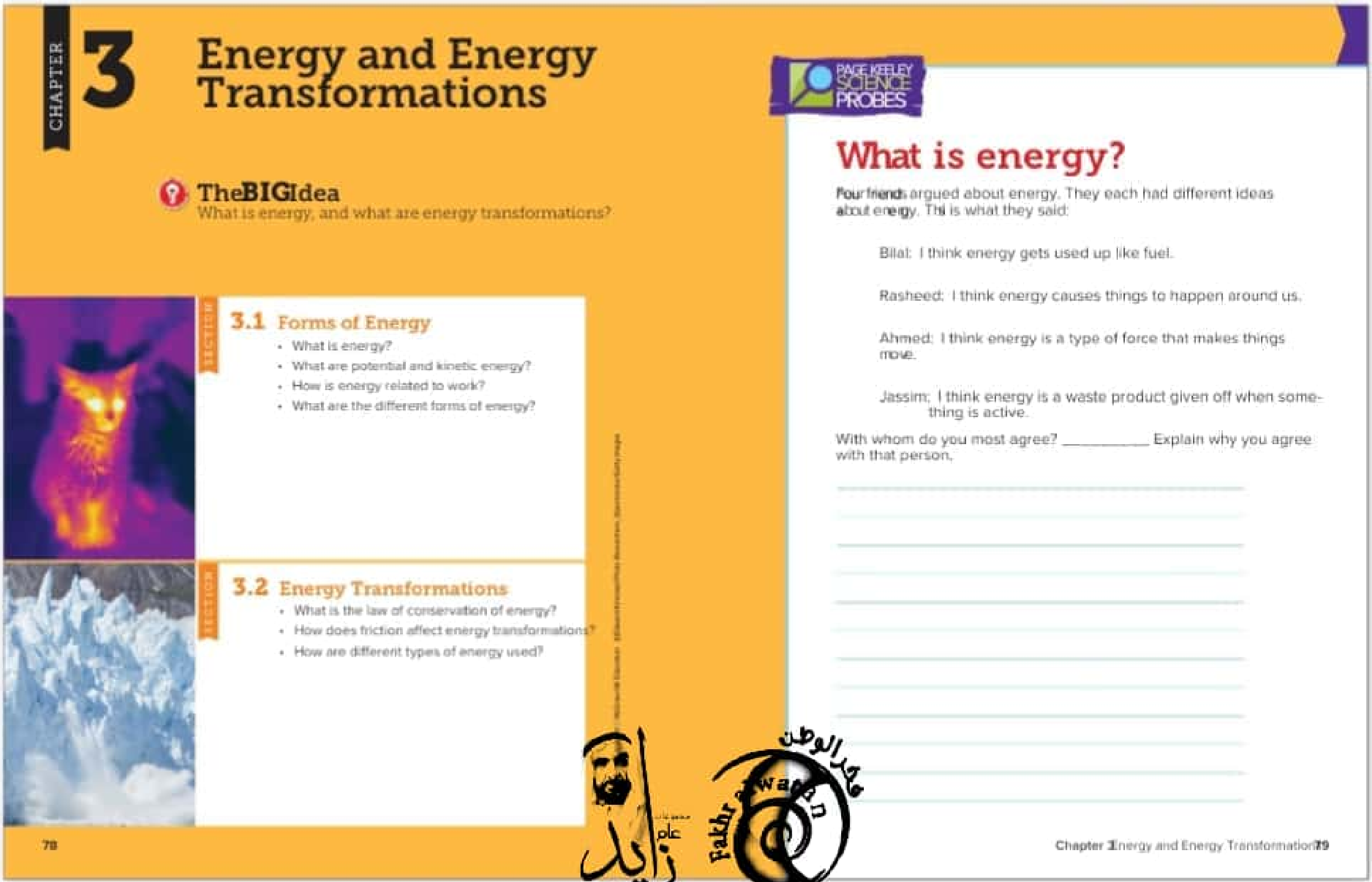
Writing in Science

21 Accept all reasonable answers. Possible answer: 1. Design a skateboard that will support 72 kg and cost no more than $30; 2. Research the materials used to make a skateboard; brainstorm possible solutions; use a Pugh Chart to determine the best solution; 4. Build a prototype; 5. Test the prototype; evaluate the prototype; 6. Redesign the prototype if necessary; communicate your results.

The BIG Idea

22 Accept all reasonable answers. Possible answer: Tools and materials help people to design, build, or use products and processes.

23 Accept all reasonable answers. Possible answer: Companies use capital to hire people and to buy materials, tools, and information to create or improve technology.


CHAPTER 3

Energy and Energy Transformations

TheBIGIdea
What is energy, and what are energy transformations?

SECTION 3.1 Forms of Energy
- What is energy?
- What are potential and kinetic energy?
- How is energy related to work?
- What are the different forms of energy?

SECTION 3.2 Energy Transformations
- What is the law of conservation of energy?
- How does friction affect energy transformations?
- How are different types of energy used?

PAGE KEELEY SCIENCE PROBES

What is energy?

Four friends argued about energy. They each had different ideas about energy. This is what they said:

Bilal: I think energy gets used up like fuel.

Rasheed: I think energy causes things to happen around us.

Ahmed: I think energy is a type of force that makes things move.

Jassim: I think energy is a waste product given off when something is active.

With whom do you most agree? __________ Explain why you agree with that person.

What is energy and what are energy transformations?

TheBIGIdea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL **What energy did you use to get to school today? How are they similar and how are they different?**	*Possible answers: breakfast, to provide energy to my body; gasoline, to fuel a car; and electricity, to move an elevator*
OL **What are the major energy transformations in the photograph?**	*Possible answers may include the Sun warming Earth or gasoline moving cars. Discuss how the Sun's energy warms Earth and helps plants grow and how fossil fuels move cars.*
BL **How could the energy resources shown in the photograph be classified?**	*The Sun may be classified as solar energy or light energy and cars as energy in motion or kinetic energy. Students might know there are different types of energy, but they may not know why they are different. This question helps students begin to differentiate forms of energy based on chemical-versus-thermal or mechanical-versus-potential characteristics.*

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about energy and energy resources. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. **A fast-moving baseball has more kinetic energy than a slow-moving baseball.**

   Agree. The faster an object moves, the more kinetic energy it has, so the fast-moving baseball would have more energy.

2. **A large truck and a small car moving at the same speed have the same kinetic energy.**

   Disagree. A large truck moving at the same speed as a small car has more kinetic energy than the car. The kinetic energy (KE) of an object depends on its speed and its mass.

3. **A book sitting on a shelf has no energy.**

   Disagree. A book sitting on a shelf has thermal energy. Also, there is gravitational potential energy between the book and Earth.

Science Content Background

Lesson 1

Forms of Energy

Kinetic and Potential Energy Energy is the ability to cause change. There are many forms of energy. Kinetic energy is energy due to motion. The faster an object moves, the more kinetic energy it has. Potential energy is stored energy—energy that comes from interactions between objects or particles. Gravitational energy is a type of potential energy.

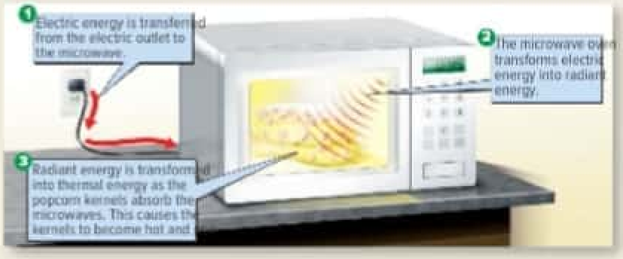
Energy and Work Energy can be transferred by doing work. Work is the application of force over a distance. For example, work is done when a person lifts an object or when one object transfers energy to another object when the two collide.

Additional Forms of Energy The energy that sound waves carry is sound energy. Energy that an electric current carries is electric energy. The energy that electromagnetic waves carry, such as energy from the Sun, is radiant energy. Energy that is stored in the nucleus of an atom is nuclear energy. Thermal energy is energy resulting from the motion of particles that make up an object. Mechanical energy is the total kinetic and potential energy in an object.

Lesson 2

Energy Transformations

Changes Between Forms of Energy Energy transformations are changes between different forms of energy, such as kinetic energy changing to potential energy and vice versa when a ball is thrown in the air and then falls down. According to the law of conservation of energy, energy can be transformed over and over again, but it cannot be created or destroyed.



Using Energy When energy is used, it is usually changed from one form to another. Turning on a light switch changes electric energy into radiant energy and thermal energy. Organisms transform chemical energy in food into kinetic energy necessary for movement.

Waste Energy When energy changes form, some thermal energy always is released, such as the thermal energy that comes from turning on a lightbulb. This thermal energy is generally not useful, and is called waste energy.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* Changes in speed or direction of motion are caused by forces.

* Substances may move from place to place but they never appear out of nowhere and never just disappear.

* Moving air and water can be used to run machines.

* Sunlight is used to run many devices.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1 Forms of Energy

1 Energy is the ability to cause change.

2 Kinetic energy is energy a body has because it is moving. Potential energy is stored energy.

3 Work is the transfer of energy that occurs when a force is applied over a distance.

4 Different forms of energy include thermal energy and radiant energy.

Lesson 2 Energy Transformations

5 According to the law of conservation of energy, energy can be transformed from one form into another or transferred from one region to another, but energy cannot be created or destroyed.

6 Friction transforms mechanical energy into thermal energy.

6 Any form of energy can be transformed into other forms of energy.

Identifying Misconcepti

Energy Is Everywhere

Find Out What Students Think

Students may think that...

... energy is only in living things. They may think of energy only as the ability of living things to grow, move, and eat, failing to understand that energy is in everything.

Discussion

Explain that energy is defined as the ability or capacity to do work or to produce change. The composition of an object and its position determines what kind of energy it has. Living things are unique in that they can convert chemical energy in food to another form, for example, thermal energy. But energy is in everything. **Ask:** What are some examples of energy that we use every day? **Students may suggest solar energy or electric energy.** Point out that the food we eat comes from solar energy and that many of the things we use each day use electric energy. Then explain that energy is present even in nonmoving objects. This type of energy is called potential energy, or stored energy.

Promote Understanding

Activity Form pairs of students. Have each pair fill large glass jars with water. Distribute lids, tea bags, and thermometers to each pair of students.

1. First, have students check the temperature of the water. Then have them add one or two tea bags to each jar. Students should cover the jars with a lid and place them in a sunny spot in the classroom.
2. In about an hour, have students remove the tea bags and check the temperature of the water
3. Have students describe what happened and why they think it happened. Have them explain where the energy came from and what energy transformations took place.
4. Have students record the process and results in their Science Journals.

Friction Is All Around

Find Out What Students Think

Students may think that...

... friction only hinders the movement of rough objects that come into contact with each other. Students may not think of friction as a constant presence that is always working against the motion of all objects that are touching.

Discussion

Refer students to **Figure 7** and review the example of friction at work from the lesson. Have students explain how the two objects (the bicycle wheel and the brake) are interacting and how the resistance from friction is affecting their slide. Clarify that friction is always present when two objects come into contact. Give the example of rubbing your hands together. **Ask:** What objects are coming into contact and how is friction affecting them? **Students should note that as your hands come into contact with each other, friction slows down their movement and creates some thermal energy.** Review with students how oil, graphite, grease, or other lubricants reduce friction but never eliminate it. There will always be some friction present when two objects touch.

Promote Understanding

Activity Bring in pictures from sports, automotive, or engineering magazines. Select a group of images that illustrate sliding, rolling, and fluid friction. Also include the iceberg photo at the beginning of **Lesson 2**, the basketball players in **Figure 6**, and/or the racing cards in **Figure 9.**

1. Form pairs of students and give each pair a few images.
2. Write the definition of friction on the board: *Friction is a force that resists the sliding of two surfaces that are touching.*
3. Clarify for students that these surfaces can include solids, liquids, and gases and that some mechanical energy is always transformed into thermal energy when two surfaces rub against each other.
4. Ask students to examine their images and locate the surfaces coming into contact.
5. Ask each pair to present their images, pinpointing where friction is at work.

SECTION

3.1 Forms of Energy

INQUIRY

Why is this cat glowing? A camera that detects temperature made this image. Dark colors represent cooler temperatures, and light colors represent warmer temperatures. Temperatures are cooler where the cat's body emits less radiant energy and warmer where the cat's body emits more radiant energy.

Write your response in your interactive notebook.

LABManager

MiniLAB Can a moving object do work?

Skill Practice Can you identify potential and kinetic energy?

80 Chapter 3

Explore Activity

Can you change matter?

You observe many things changing. Birds change their positions when they fly. Bubbles form in boiling water. The filament in a lightbulb glows when you turn on a light. How can you cause a change in matter?

1. Read and complete the lab safety form.
2. Half-fill a **foam cup** with **sand**. Place the bulb of a **thermometer** about halfway into the sand. *Do not stir.* Record the temperature in your Science Journal.
3. Remove the thermometer and place a **lid** on the cup. Hold down the lid and shake the cup vigorously for 10 min.
4. Remove the lid. Measure and record the temperature of the sand.

Think About This

1. What change did you observe in the sand?
2. How could you change your results?
3. **Key Concept** What do you think caused the change you observed in the sand?

Essential Questions

- What is energy?
- What are potential and kinetic energy?
- How is energy related to work?
- What are the different forms of energy?

Vocabulary

energy
kinetic energy
potential energy
work
mechanical energy
sound energy
thermal energy
electric energy
radiant energy
nuclear energy

81

INQUIRY

About the Photo **Why is this cat glowing?** Help students understand that the colors in this picture result from thermal energy, not light energy. Remind students that different amounts of thermal energy travel to the camera as radiant energy of infrared light. Use the questions below to start a discussion about radiant and thermal energy. Then lead a class discussion about the forms of energy, and see if students can suggest any other forms of energy.

Guiding Questions

AL In this image, what are some of the cat's warmest areas?	*Possible answers may include its eyes, mouth, ears, face, and paws.*
OL How does the cat's fur affect colors in this image? How would shaving the cat affect the colors?	*The brightness depends on the thickness of the cat's fur—the thicker, the darker. If the cat were shaved, the image would be brighter.*
BL Where would a car's brightest and darkest areas be if it had just finished a long drive?	*The hood and wheels would be brightest. The windows might glow if the the heater were on. The sides, top, and trunk would be darker because they would be cool.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook and the Activity Lab Workbook.*

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Brainstorm: Where can you find energy?

1. Form groups of four students. Have each group brainstorm 15 examples of energy. Try to guide the brainstorming from examples in daily life, such as food, toward energy sources that students do not experience often, such as nuclear energy. Summarize all the examples by writing them on chart paper or on the board.
2. **Ask:** **How would you group (classify) these examples?** *Challenge students to find common as well as uncommon ways to classify their examples of energy. Students may notice the definitions in the vocabulary list and opt to use these.*

3. Have students share their classifications and write them on the board. Point out similarities between students' classifications and those used in this lesson: kinetic energy, potential energy, mechanical energy, sound energy, light energy, thermal energy, electric energy, radiant energy, and nuclear energy.

Teacher Notes

Explore Activity

Can you change matter?

Prep: *5 min* **Class:** *15 min*

Purpose
To observe the relationship between motion, energy, and temperature.

Materials
Students: polystyrene cup with lid, sand (or rice), thermometer

Before You Begin
Form teams of two and provide each team with a set of materials.

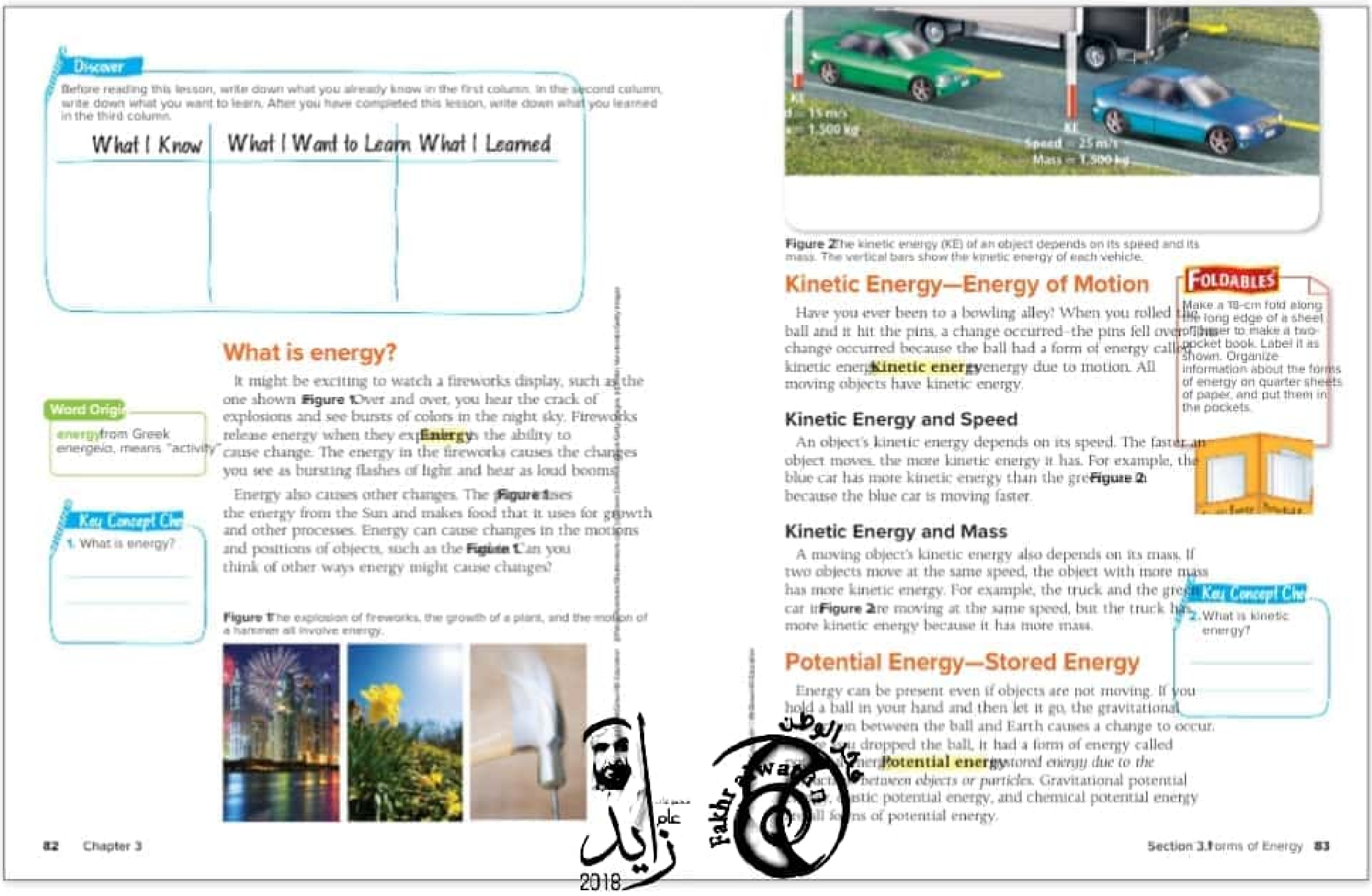
Guide the Investigation

- Have students use previous experiences to discuss the types of changes that can occur to matter, including changes in shape, size, temperature, color, positions of objects, and an object's composition, such as when food is cooked.
- If students use glass thermometers, caution them to be careful when placing thermometers in sand. Make sure that students do not attempt to shake their cups with thermometers in them or use thermometers to stir sand.
- Encourage students to take turns and shake the cup vigorously for at least 2 min.
- A variation on the procedure is to half-fill one cup with rice or sand, take the temperature, and then tape the rim of an empty cup to this cup's rim. This gives the sand or rice twice the room to move while the cup is being shaken.

Think About This
Do not expect students to determine the correct answer. Students should be encouraged to speculate. Use the answer set to guide students' reasoning.

1. Students should observe that the temperature of the sand increased several degrees after shaking. Students may infer that the sand rubbing together while it was shaken caused the increase in temperature.
2. Students may suggest that they could have shaken the sand longer to increase the temperature even more.
3. Students may conclude that the energy they used in shaking the cup was somehow transferred to the sand. The increased energy in the sand caused an increase in temperature.

OL On Level AL Approaching Level BL Beyond Level



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Word Origin
energy from Greek energeia, means "activity"

Key Concept Check
1. What is energy?

What is energy?

It might be exciting to watch a fireworks display, such as the one shown Figure 1. Over and over, you hear the crack of explosions and see bursts of colors in the night sky. Fireworks release energy when they explode. Energy is the ability to cause change. The energy in the fireworks causes the changes you see as bursting flashes of light and hear as loud booms.

Energy also causes other changes. The plant in Figure 1 uses the energy from the Sun and makes food that it uses for growth and other processes. Energy can cause changes in the motions and positions of objects, such as the hammer in Figure 1. Can you think of other ways energy might cause changes?

Figure 1 The explosion of fireworks, the growth of a plant, and the motion of a hammer all involve energy.

Figure 2 The kinetic energy (KE) of an object depends on its speed and its mass. The vertical bars show the kinetic energy of each vehicle.

Kinetic Energy—Energy of Motion

Have you ever been to a bowling alley? When you rolled the ball and it hit the pins, a change occurred–the pins fell over. This change occurred because the ball had a form of energy called kinetic energy. Kinetic energy is energy due to motion. All moving objects have kinetic energy.

FOLDABLES
Make a 18-cm fold along the long edge of a sheet of paper to make a two-pocket book. Label it as shown. Organize information about the forms of energy on quarter sheets of paper, and put them in the pockets.

Kinetic Energy and Speed

An object's kinetic energy depends on its speed. The faster an object moves, the more kinetic energy it has. For example, the blue car has more kinetic energy than the green car in Figure 2 because the blue car is moving faster.

Kinetic Energy and Mass

A moving object's kinetic energy also depends on its mass. If two objects move at the same speed, the object with more mass has more kinetic energy. For example, the truck and the green car in Figure 2 are moving at the same speed, but the truck has more kinetic energy because it has more mass.

Key Concept Check
2. What is kinetic energy?

Potential Energy—Stored Energy

Energy can be present even if objects are not moving. If you hold a ball in your hand and then let it go, the gravitational interaction between the ball and Earth causes a change to occur. Before you dropped the ball, it had a form of energy called potential energy. Potential energy is *stored energy due to the interactions between objects or particles.* Gravitational potential energy, elastic potential energy, and chemical potential energy are all forms of potential energy.

What is energy?

Use this question to help students connect the Launch Lab observations to the definition of energy. Help students understand that a change is the only way to detect energy.

Ask: **What is energy?** *Energy is the ability to cause change.*

Word Origin

energy

Ask: **How does the word *energy* relate to the word *activity*?** *Students might say that energy is the ability to cause change, and an activity is the result of that change. For example, the activity of boiling water uses energy released from a flame.*

Ask: **What might be the energy source of the hammer in Figure 1?** *Possible answers include a person or machine. You can produce the activity of hammering by using human energy or a machine.*

Kinetic Energy—Energy of Motion

Visual Literacy: Figure 2

Students often associate kinetic energy with speed, but they may need to be reminded that it also depends on mass, as shown in **Figure 2**.

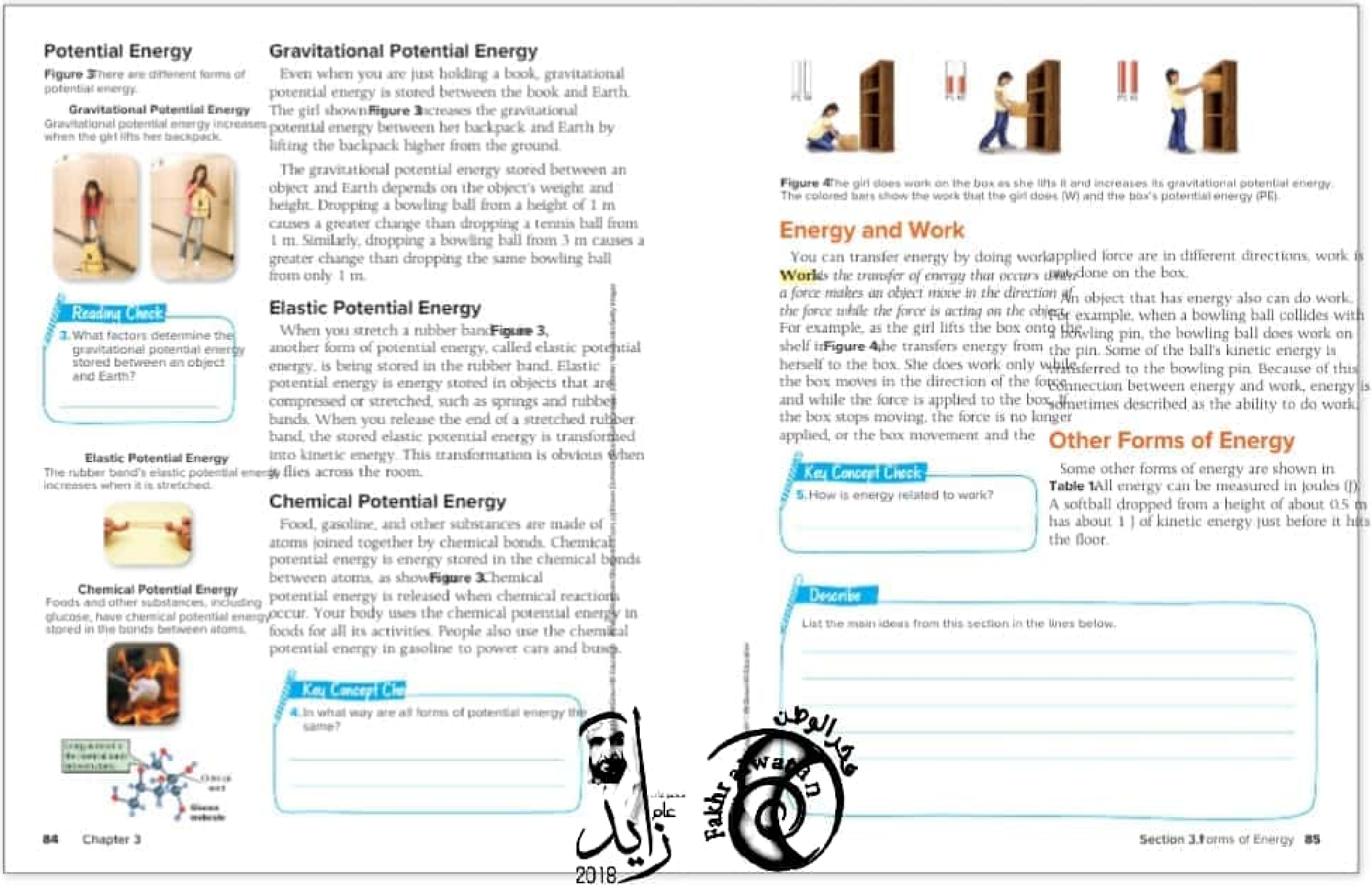
Ask: **How could the truck moving at the same speed as the green car have more kinetic energy?** *Students should note that the car and truck are moving at the same speed, but the truck has more mass.*

Kinetic Energy and Speed

Use the following questions to help students understand the relationship between the speed of a moving object and its kinetic energy.

Guiding Questions

AL Give examples of objects with and without kinetic energy.	*Possible answers: a moving car has kinetic energy and a parked car has no kinetic energy.*
OL Explain how a fast-moving bowling ball can cause more change than a slow-moving bowling ball.	*The fast-moving bowling ball has more kinetic energy than a slow-moving one and can cause more change because it is moving faster.*
BL How does kinetic energy change as you quickly walk to your class and then sit at your desk?	*As you quickly walk, motion and kinetic energy increase; both decrease when you sit down.*



Potential Energy

Figure 3 There are different forms of potential energy.

Gravitational Potential Energy
Gravitational potential energy increases when the girl lifts her backpack.

Reading Check
3. What factors determine the gravitational potential energy stored between an object and Earth?

Elastic Potential Energy
The rubber band's elastic potential energy increases when it is stretched.

Chemical Potential Energy
Foods and other substances, including glucose, have chemical potential energy stored in the bonds between atoms.

Gravitational Potential Energy

Even when you are just holding a book, gravitational potential energy is stored between the book and Earth. The girl shown in **Figure 3** increases the gravitational potential energy between her backpack and Earth by lifting the backpack higher from the ground.

The gravitational potential energy stored between an object and Earth depends on the object's weight and height. Dropping a bowling ball from a height of 1 m causes a greater change than dropping a tennis ball from 1 m. Similarly, dropping a bowling ball from 3 m causes a greater change than dropping the same bowling ball from only 1 m.

Elastic Potential Energy

When you stretch a rubber band in **Figure 3**, another form of potential energy, called elastic potential energy, is being stored in the rubber band. Elastic potential energy is energy stored in objects that are compressed or stretched, such as springs and rubber bands. When you release the end of a stretched rubber band, the stored elastic potential energy is transformed into kinetic energy. This transformation is obvious when it flies across the room.

Chemical Potential Energy

Food, gasoline, and other substances are made of atoms joined together by chemical bonds. Chemical potential energy is energy stored in the chemical bonds between atoms, as shown in **Figure 3**. Chemical potential energy is released when chemical reactions occur. Your body uses the chemical potential energy in foods for all its activities. People also use the chemical potential energy in gasoline to power cars and buses.

Key Concept Check
4. In what way are all forms of potential energy the same?

84 Chapter 3

Figure 4 The girl does work on the box as she lifts it and increases its gravitational potential energy. The colored bars show the work that the girl does (W) and the box's potential energy (PE).

Energy and Work

You can transfer energy by doing work. **Work** is *the transfer of energy that occurs when a force makes an object move in the direction of the force while the force is acting on the object.* For example, as the girl lifts the box onto the shelf in **Figure 4**, she transfers energy from herself to the box. She does work only while the box moves in the direction of the force and while the force is applied to the box. If the box stops moving, the force is no longer applied, or the box movement and the applied force are in different directions, work is not done on the box.

An object that has energy also can do work. For example, when a bowling ball collides with a bowling pin, the bowling ball does work on the pin. Some of the ball's kinetic energy is transferred to the bowling pin. Because of this connection between energy and work, energy is sometimes described as the ability to do work.

Key Concept Check
5. How is energy related to work?

Other Forms of Energy

Some other forms of energy are shown in **Table 1**. All energy can be measured in joules (J). A softball dropped from a height of about 0.5 m has about 1 J of kinetic energy just before it hits the floor.

Describe
List the main ideas from this section in the lines below.

Section 3.1 Forms of Energy 85

Gravitational Potential Energy

Use the following questions to review factors that determine gravitational potential energy of an object.

Guiding Questions

AL Give examples of objects with gravitational potential energy.	*Possible answers may include a book lifted off a desk; a diver on a diving board; and an airplane in flight.*
OL What factors determine the gravitational potential energy stored between an object and Earth?	*An object's weight and its height above Earth determine gravitational potential energy. A book bag held above one's head has more gravitational potential energy than a book bag held at waist level. The same bag at waist level has more gravitational potential energy if it is full than when it is empty.*
BL How could gravitational potential energy power devices when electricity is not available?	*Weights can be attached to power devices. Raised weights on clocks store gravitational potential energy that then turn the hands of the clock.*

Elastic Potential Energy

Use these questions to help students understand the concept of elastic potential energy.

Guiding Questions

AL What changes when an elastic band is stretched?	*The elastic potential energy increases when the elastic band is elongated and deformed. This change in shape is where the elastic potential energy is stored; the elastic band will cause change in order to return to its original shape.*
OL Name some materials that might store a lot of elastic potential energy. How are all of these materials similar?	*Possible answers may include a rubber band, a basketball, a metal spring, or any object that can be deformed and then return to its original shape. All these objects can store elastic potential energy.*
BL What characteristics make an object effective at storing elastic potential energy?	*An object must be able to withstand a change in shape—flexibility—and also quickly return to its original shape. A basketball, for example, flexes when it hits the floor but immediately returns to its original shape.*

Chemical Potential Energy

Use the following questions to help students understand that chemical compounds contain potential energy.

Guiding Questions

AL Give three examples of chemical potential energy in your life today.	*Possible answers may include food, gasoline, and firewood.*

OL In what way are all forms of potential energy the same?	*All forms of potential energy are stored energy.*
BL How are the calorie contents of various foods related to their potential energy?	*Calories are one way of measuring the amount of energy that food contains. As the calorie count increases, the amount of chemical potential energy increases. For example, ice cream has more chemical potential energy per gram than celery, because each unit of ice cream has more chemical bonds or higher-energy chemical bonds.*

Energy and Work

Stress the difference between energy and work. Work is the transfer of energy. When work is done on an object, the object's energy increases. When work is done by an object, its energy decreases. Use the questions below to discuss the relationship between energy and work.

Guiding Questions

AL Give some examples of how energy can help you do work.	*Possible answers may include lifting a book up onto a shelf, creating sounds, and riding an elevator to move between the floors of a building.*
OL How is energy related to work?	*Work is the transfer of energy that occurs when a force causes an object to move. For example, a car at the top of a hill has potential energy because work was done to move it up the hill.*
BL Does a person work when he or she lifts a box? Does a person work when he or she holds a box in the air?	*Work is done when lifting the box, but not by holding the box because there is no change in the position of the box.*

Other Forms of Energy

An effective way to get students to classify other forms of energy is by using the examples in **Table 1** on the next page. Have students use the examples as a starting point for other possibilities.

Differentiated Instruction

AL **Local Energy Use** Have students create an album of examples of energy use in their lives. They can draw pictures, cut them out of magazines, or copy them from library pictures. Ask students to write a short caption fo each picture that includes the type of energy it illustrate For example, they may write *electric energy* or *radiant energy* next to a lightbulb; *nuclear energy* next to a sta the Sun; *radiant energy* next to solar panels, and *sounc energy* above a picture of a radio.

BL **A Day in the Life of Energy** Have students, in pairs or groups of three, outline and write a short skit that follov energy through one day as it transforms from one type another. Have students begin by using the reading to li the types of potential and kinetic energy they will incluc their work. Then, have them brainstorm how those type energy exist in a classroom. Finally, have students demonstrate how those types of energy can be linked together in a 5-min episode.

Teacher Toolbox

Reading Strategy

Working in pairs, have students challenge their partne identify how each type of kinetic energy and each type potential energy relate to each energy in **Table 1**. Students should then challenge each other to describe type of work done by each type of energy in **Table 1**.

Fun Fact

Fusion v. Chemical Reaction The energy from a hydrogen nuclear reaction is over 1 million times more powerful t the chemical reaction of burning hydrogen.

Careers in Science

Design Sculptors Nearly all automobiles begin as model At some point, those models need to be tested for ene efficiency to help engineers decide how to minimize e consumption and maximize speed, safety, and utility. Automobile engineers work with professional sculptor take the engineers' ideas and create an exact scale m of the car out of foam and clay. Design sculptors are a important link in the process of creating new, more eff means of transportation for the future.

OL On Level AL Approaching Level BL Beyond Level

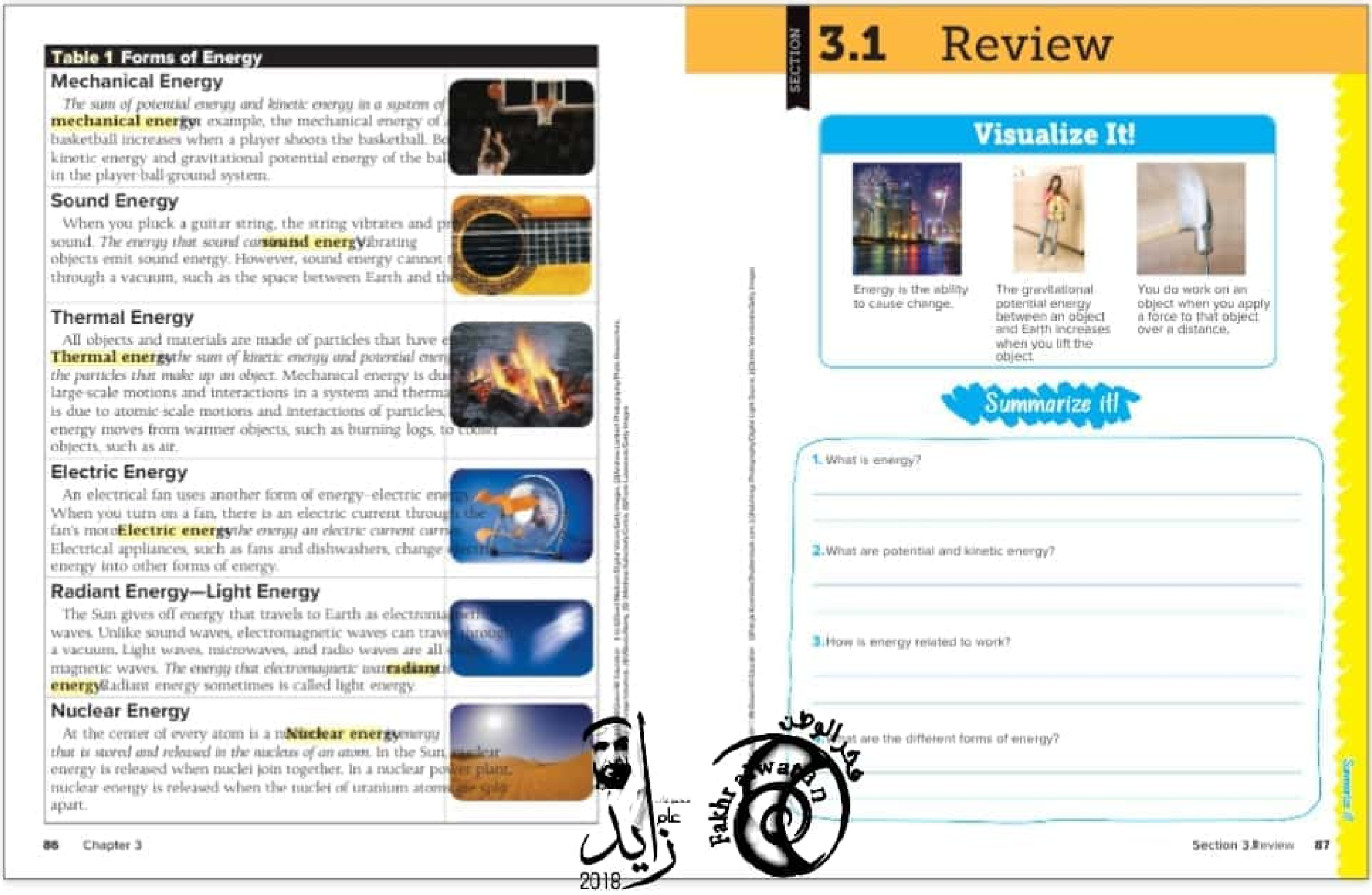


Table 1 Forms of Energy

Mechanical Energy

The sum of potential energy and kinetic energy in a system of **mechanical energy**r example, the mechanical energy of a basketball increases when a player shoots the basketball. Bo kinetic energy and gravitational potential energy of the bal in the player-ball-ground system.

Sound Energy

When you pluck a guitar string, the string vibrates and pr sound. *The energy that sound ca***sound energy**ibrating objects emit sound energy. However, sound energy cannot through a vacuum, such as the space between Earth and th

Thermal Energy

All objects and materials are made of particles that have e **Thermal energy***the sum of kinetic energy and potential ener the particles that make up an object.* Mechanical energy is du large-scale motions and interactions in a system and therma is due to atomic-scale motions and interactions of particles, energy moves from warmer objects, such as burning logs, to cooler objects, such as air.

Electric Energy

An electrical fan uses another form of energy–electric energy. When you turn on a fan, there is an electric current through the fan's moto**Electric energy***the energy an electric current carr* Electrical appliances, such as fans and dishwashers, change energy into other forms of energy.

Radiant Energy—Light Energy

The Sun gives off energy that travels to Earth as electroma waves. Unlike sound waves, electromagnetic waves can trav a vacuum. Light waves, microwaves, and radio waves are all magnetic waves. *The energy that electromagnetic wa***radiant energy**Radiant energy sometimes is called light energy.

Nuclear Energy

At the center of every atom is a n**Nuclear energy***energy that is stored and released in the nucleus of an atom.* In the Sun, nuclear energy is released when nuclei join together. In a nuclear power plant, nuclear energy is released when the nuclei of uranium atoms are split apart.

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SECTION **3.1 Review**

Visualize It!

Energy is the ability to cause change.

The gravitational potential energy between an object and Earth increases when you lift the object.

You do work on an object when you apply a force to that object over a distance.

Summarize it!

1. What is energy?
2. What are potential and kinetic energy?
3. How is energy related to work?
4. What are the different forms of energy?

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Visual Literacy: Forms of Energy

Use the questions below to help students better understand the forms of energy by asking them to give examples from their lives.

Mechanical Energy / Sound Energy

Guiding Questions

AL	Is a car in motion an example of mechanical or sound energy? How about a loud classroom?	*A car in motion shows mechanical energy. A loud classroom, like a stereo or an explosion, emits sound energy.*
OL	What do mechanical energy and sound energy have in common?	*Both types of energy have the ability to cause change.*
BL	How are mechanical energy and sound energy different?	*Mechanical energy is related to objects; sound is related to waves.*

Thermal Energy / Electric Energy

Guiding Questions

AL	What kind of energy does an oven use? Does a television use thermal or electric energy?	*A hot oven gives off thermal energy to cook. A television uses electric energy to display images and emit sound.*
OL	What other items are called thermal? What do these items do?	*Possible answers may include thermal blankets and thermal underwear. Both items are related to heat.*
BL	How can thermal energy be used to make electric energy? How can electric energy be used to create thermal energy?	*Thermal energy can cause water to turn to steam that can turn a turbine connected to a generator, which will then create an electric current. Electric energy heats a wire as it flows it, as in a toaster.*

Radiant Energy—Light Energy / Nuclear Energy

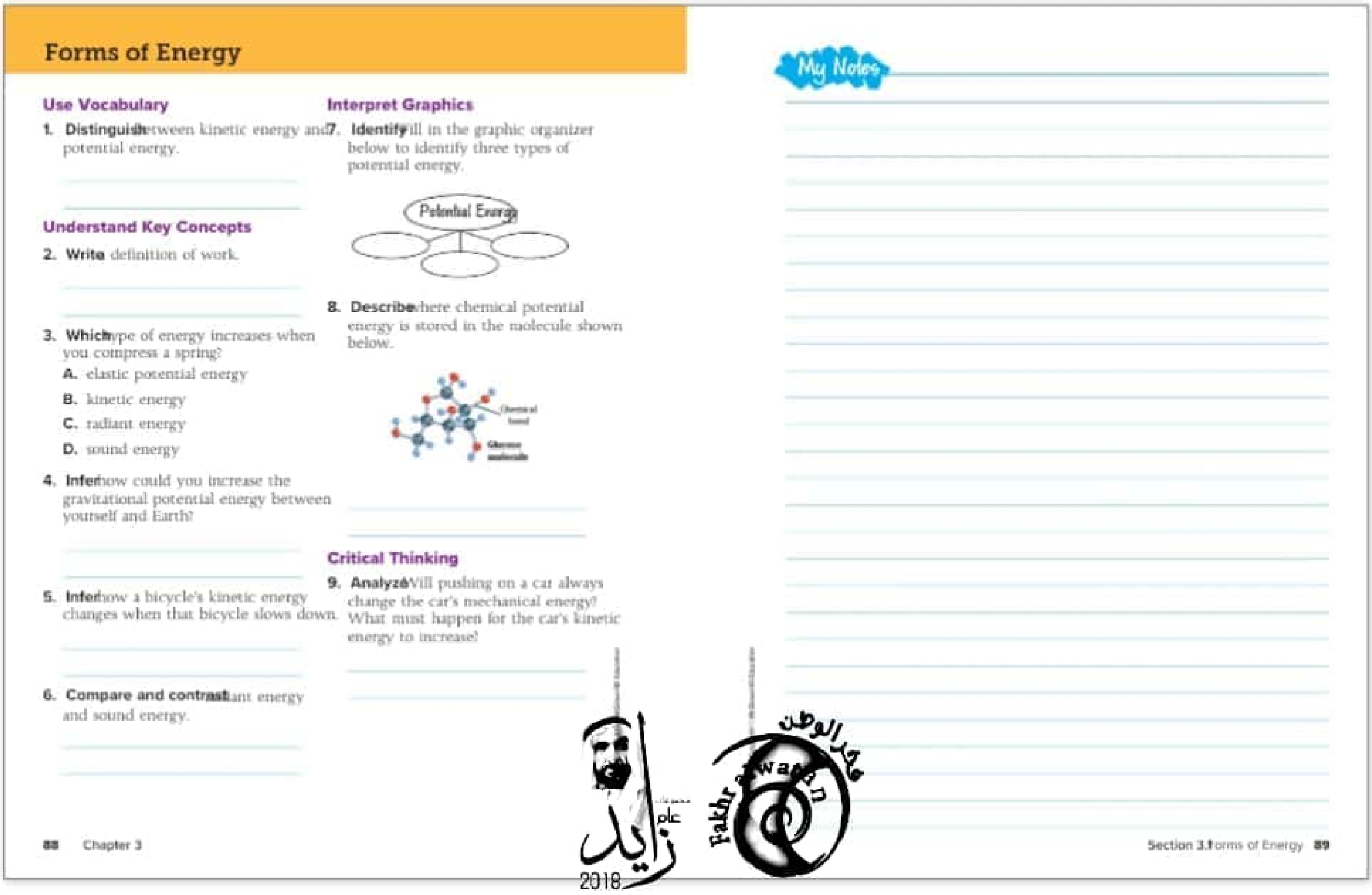
Guiding Questions

AL	What objects can you think of that shine?	*Answers may include objects that emit light, such as the Sun, stars, flashlights, and lightbulbs.*
OL	Describe three forms of energy.	*The energy given off by the Sun is radiant energy. The energy stored in the nucleus of an atom is nuclear energy. The energy carried by sound waves is sound energy.*
BL	How can one energy resource—for example, the Sun—be the source of multiple types of energy?	*The Sun is made up of atoms whose nuclei store energy. Energy from these nuclei is released in the form of thermal energy and radiant energy.*

Visual Summary

Ask: Which Key Concept does each image relate to?

Summarize it!


Forms of Energy

Use Vocabulary

1. **Distinguish** between kinetic energy and potential energy.

Understand Key Concepts

2. **Write** definition of work.
3. **Which** type of energy increases when you compress a spring?
   - **A.** elastic potential energy
   - **B.** kinetic energy
   - **C.** radiant energy
   - **D.** sound energy
4. **Infer** how could you increase the gravitational potential energy between yourself and Earth?
5. **Infer** how a bicycle's kinetic energy changes when that bicycle slows down.
6. **Compare and contrast** radiant energy and sound energy.

Interpret Graphics

7. **Identify** Fill in the graphic organizer below to identify three types of potential energy.

8. **Describe** where chemical potential energy is stored in the molecule shown below.

Critical Thinking

9. **Analyze** Will pushing on a car always change the car's mechanical energy? What must happen for the car's kinetic energy to increase?

My Notes

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Section 3.1 Forms of Energy 89

Use Vocabulary

1. Kinetic energy is energy due to motion; potential energy is stored energy due to the interactions between objects or particles. **DOK 1**

Understand Key Concepts

2. Possible answer: Work is the transfer of energy that occurs when a force is applied over a distance. **DOK 1**

3. **A.** elastic potential energy **DOK 2**

4. You could increase the gravitational potential energy between yourself and Earth by climbing stairs because you are moving higher. **DOK 3**

5. The kinetic energy decreases as a bicycle slows down. **DOK 3**

6. Both sound energy and radiant energy travel in waves. Light is radiant energy. Sound waves carry sound energy. Light waves travel faster than sound waves. **DOK 2**

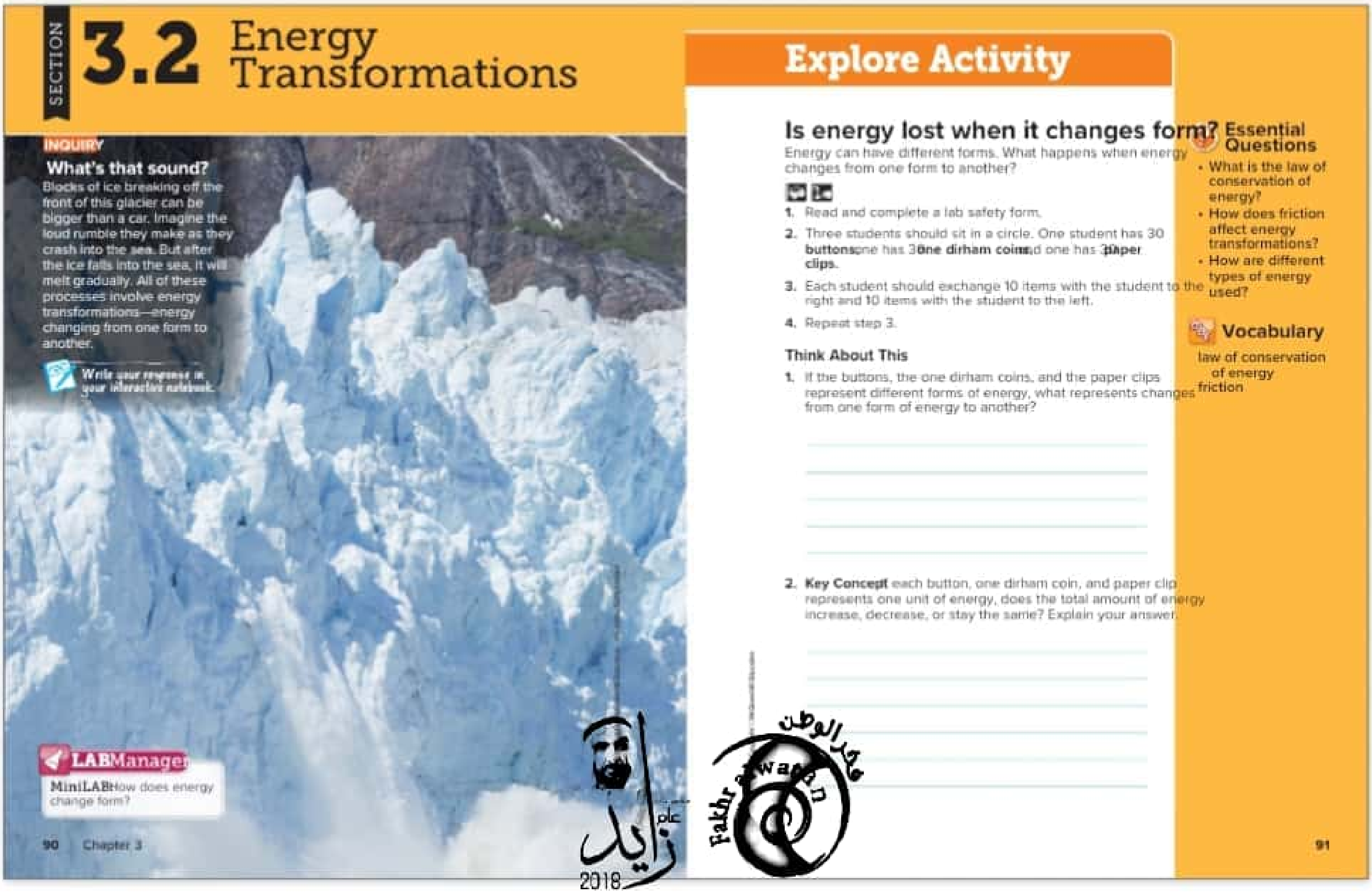
Interpret Graphics

7. gravitational; elastic; chemical (in any order) **DOK 2**

8. Chemical potential energy is stored in the chemical bonds in the molecule below. **DOK 3**

Critical Thinking

9. Pushing on a car will not always change the car's kinetic energy. To change the car's kinetic energy, the car must move. **DOK 4**



SECTION 3.2 Energy Transformations

INQUIRY

What's that sound?

Blocks of ice breaking off the front of this glacier can be bigger than a car. Imagine the loud rumble they make as they crash into the sea. But after the ice falls into the sea, it will melt gradually. All of these processes involve energy transformations—energy changing from one form to another.

Write your response in your interactive notebook.

LABManager

MiniLAB How does energy change form?

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Explore Activity

Is energy lost when it changes form?

Energy can have different forms. What happens when energy changes from one form to another?

1. Read and complete a lab safety form.
2. Three students should sit in a circle. One student has 30 **buttons** one has 30 **one dirham coins**, and one has 30 **paper clips**.
3. Each student should exchange 10 items with the student to the right and 10 items with the student to the left.
4. Repeat step 3.

Think About This

1. If the buttons, the one dirham coins, and the paper clips represent different forms of energy, what represents changes from one form of energy to another?
2. **Key Concept** each button, one dirham coin, and paper clip represents one unit of energy, does the total amount of energy increase, decrease, or stay the same? Explain your answer.

Essential Questions

- What is the law of conservation of energy?
- How does friction affect energy transformations?
- How are different types of energy used?

Vocabulary

law of conservation of energy

friction

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INQUIRY

About the Photo **What's that sound?** Direct students to use **Table 1** to describe which types of energy are shown, and prompt them to observe any changes from one form of energy to another.
Bring the terms *potential energy* and *kinetic energy* into the discussion.
Help students identify examples of one form of energy transforming into another in this photo.

Guiding Questions

OL The radiant energy in sunlight heats ice, melting it and causing it to fall all in a series of energy transformations. Describe your own series of energy transformations.	*Possible answers may include sunlight (radiant energy) heats the air (thermal energy), which melts the ice, causing it to fall (releasing potential energy) and to make noise (sound energy) and waves (kinetic energy).*
BL Describe a set of transformations similar to the one shown in the picture that could possibly happen in your town.	*Possible answers may include a car engine that starts (mechanical energy), powers the car out of the driveway (kinetic energy), and quickly drives the car to the top of the hill (potential energy); sunlight (radiant energy) melts snow (thermal energy) on the roof (gravitational potential energy); which then falls to the ground (kinetic energy).*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Build a Class Definition

1. Explain briefly that one of nature's laws is that energy is conserved and only changes form. The total amount of energy remains constant. Write the words *law of conservation of energy* on the board. **Ask: What are some examples of energy being used in your daily life?**
2. Form student groups and choose one student from each group to quickly shout out an example of energy being used.

3. Then, challenge them to invent the best brief story or illustration of the law of conservation of energy. Remind them that there are many types of energy, and one type can become another. Have one or two groups share their explanations of how it is possible that the total amount of energy remains the same even after changing form.
4. Finally, challenge each group to write their interpretation of the law of conservation of energy.

Teacher Notes

Explore Activity

Is energy lost when it changes forms?

Prep: *5 min* **Class:** *15 min*

Purpose
To infer energy transformations in change and the conservation of energy.

Materials
3 plastic sandwich bags (one containing 30 buttons, one containing 30 pennies, one containing 30 paper clips). Small washers or pasta shells may also be substituted.

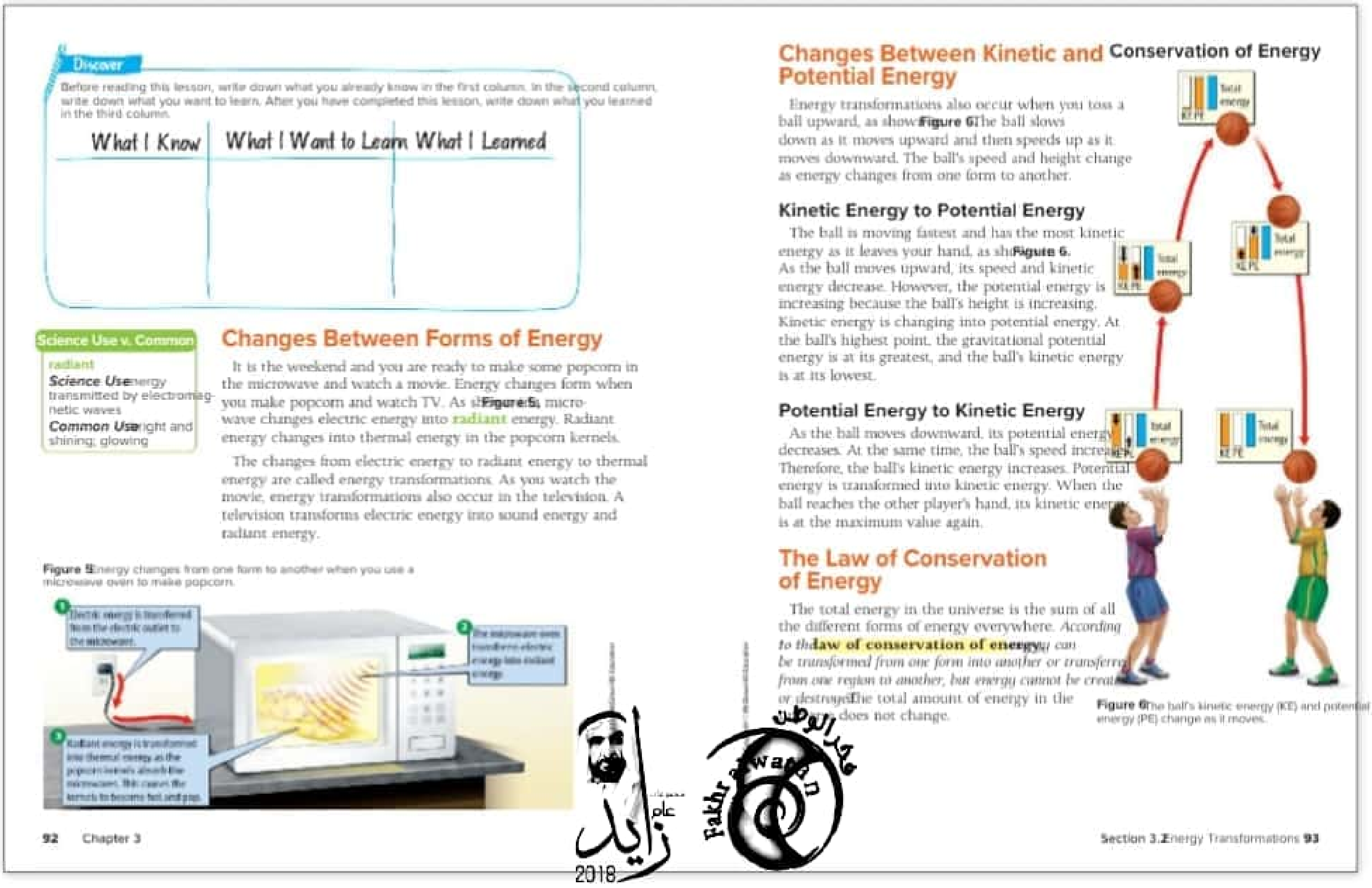
Before You Begin
Prepare one set of bags for each group of three.

Guide the Investigation

- Discuss the meaning of *transform*. The prefix *trans-* means "move across." *Transform* is to move from one form to another. Ask students for examples in daily life of how energy transforms (lightning, lighting a match, turning on a lightbulb).
- Explain that the objects in the activity represent different forms of energy, such as electricity, heat, or light. Each object represents one unit of energy. When energy changes from one form to the next, in this case by moving from one bag to another, none of the energy is lost.

Think About This
Do not expect students to determine the correct answer. Students should be encouraged to speculate. Use the answer set to guide students' reasoning.

1. Exchanging one type of object for another represented changes in energy from one type to another. Each student ended up with different types of energy from what they started with to represent that energy was transformed.
2. The total amount of energy is the same, even though it is located in different places and is present in different forms.


Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Science Use v. Common

radiant

Science Use energy transmitted by electromagnetic waves

Common Use bright and shining; glowing

Changes Between Forms of Energy

It is the weekend and you are ready to make some popcorn in the microwave and watch a movie. Energy changes form when you make popcorn and watch TV. As shown in **Figure 5**, a microwave changes electric energy into radiant energy. Radiant energy changes into thermal energy in the popcorn kernels.

The changes from electric energy to radiant energy to thermal energy are called energy transformations. As you watch the movie, energy transformations also occur in the television. A television transforms electric energy into sound energy and radiant energy.

Figure 5 Energy changes from one form to another when you use a microwave oven to make popcorn.

Changes Between Kinetic and Potential Energy

Energy transformations also occur when you toss a ball upward, as shown in **Figure 6**. The ball slows down as it moves upward and then speeds up as it moves downward. The ball's speed and height change as energy changes from one form to another.

Kinetic Energy to Potential Energy

The ball is moving fastest and has the most kinetic energy as it leaves your hand, as shown in **Figure 6.** As the ball moves upward, its speed and kinetic energy decrease. However, the potential energy is increasing because the ball's height is increasing. Kinetic energy is changing into potential energy. At the ball's highest point, the gravitational potential energy is at its greatest, and the ball's kinetic energy is at its lowest.

Potential Energy to Kinetic Energy

As the ball moves downward, its potential energy decreases. At the same time, the ball's speed increases. Therefore, the ball's kinetic energy increases. Potential energy is transformed into kinetic energy. When the ball reaches the other player's hand, its kinetic energy is at the maximum value again.

The Law of Conservation of Energy

The total energy in the universe is the sum of all the different forms of energy everywhere. *According to the* **law of conservation of energy**, *energy can be transformed from one form into another or transferred from one region to another, but energy cannot be created or destroyed.* The total amount of energy in the universe does not change.

Conservation of Energy

Figure 6 The ball's kinetic energy (KE) and potential energy (PE) change as it moves.

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Section 3.2 Energy Transformations 93

Changes Between Forms of Energy

Students may readily understand transformation of energy but not realize how common it is in daily life. **Figure 5** traces energy transformations in a common kitchen setting. Refer students to the forms of energy listed in **Table 1** in **Lesson 1.**

Guiding Questions

AL What energy transformations do you see in **Figure 5**?	*Possible answers: fan, electricity into kinetic energy; lightbulb emitting radiant energy; electricity into microwaves; popcorn, radiant energy into thermal energy*
OL What energy transformation takes place when you slam a door?	*Kinetic energy is transferred into sound energy and thermal energy.*
BL Describe another kind of energy transformation that can take place in your kitchen.	*Possible answers: oven, electric energy into thermal energy; blender, electric energy into kinetic energy*

Science Use v. Common Use

radiant

Radiant comes from the Latin, *radians*, meaning "to shine." Explain that scientists use *radiant* to describe energy transmitted by electromagnetic waves.

Ask: **What do the science use and common use of the word radiant have in common?** *Both terms refer to something that is being given off or being emitted.*

Changes Between Kinetic and Potential Energy

Refer students to **Figure 6**. Remind students that as an object rises then falls back to Earth, the total amount of energy remains constant.

Visual Literacy: Conservation of Energy

Ask: **What are other examples of a change between potential and kinetic energy?** *Possible answers may include an elastic band being stretched and released; a car driving over a hill; a pendulum swinging.*

Ask: **When is the gravitational potential energy the greatest?** *When the ball is at the top of its trajectory.*

Kinetic Energy to Potential Energy

Remind students that kinetic energy can turn into other kinds of potential energy, including elastic potential energy, gravitational potential energy, and electric potential energy.

Guiding Questions

AL How are potential and kinetic energy different?	*Potential energy is the energy an object has because of its position. Kinetic energy is the energy an object has because of its motion.*

Potential Energy to Kinetic Energy

Gravitational potential energy is an excellent way to introduce the law of conservation of energy. But continue to remind students that potential energy takes many forms, including chemical, elastic, and electric.

Guiding Questions

OL Why does the potential energy decrease as the ball falls?	*The ball's height decreases as it falls.*

The Law of Conservation of Energy

Students often confuse the loss of energy with the transformation of energy. Help them work through the idea of conservation of energy by following the energy transformations in **Figure 6**.

Guiding Questions

OL What is the law of conservation of energy?	*Energy can be transformed from one form to another or transferred from one region to another, but it cannot be created or destroyed.*

Differentiated Instruction

AL **Illustrate Energy Transformations** Have students choose partners and create three illustrations of instan where kinetic energy is transformed to thermal energy students to examine machines and natural occurrence around them for ideas. Some instances should show o in motion and some at rest. Each illustration should use labels to show where friction occurred and where ther energy went. In addition, each should include graphs showing the relative amounts of kinetic energy and the energy.

BL **Graphing** Have students research and graph the sp of a space shuttle or a meteorite as it enters Earth's atmosphere and slows because of friction. Then by eit researching or estimating, students should create a gra increasing thermal energy for the same object.

Teacher Toolbox

Teacher Demo/Activity

Friction

1. Ask students to rub their hands together quickly. Th them to stop rubbing and immediately shake hands another student.

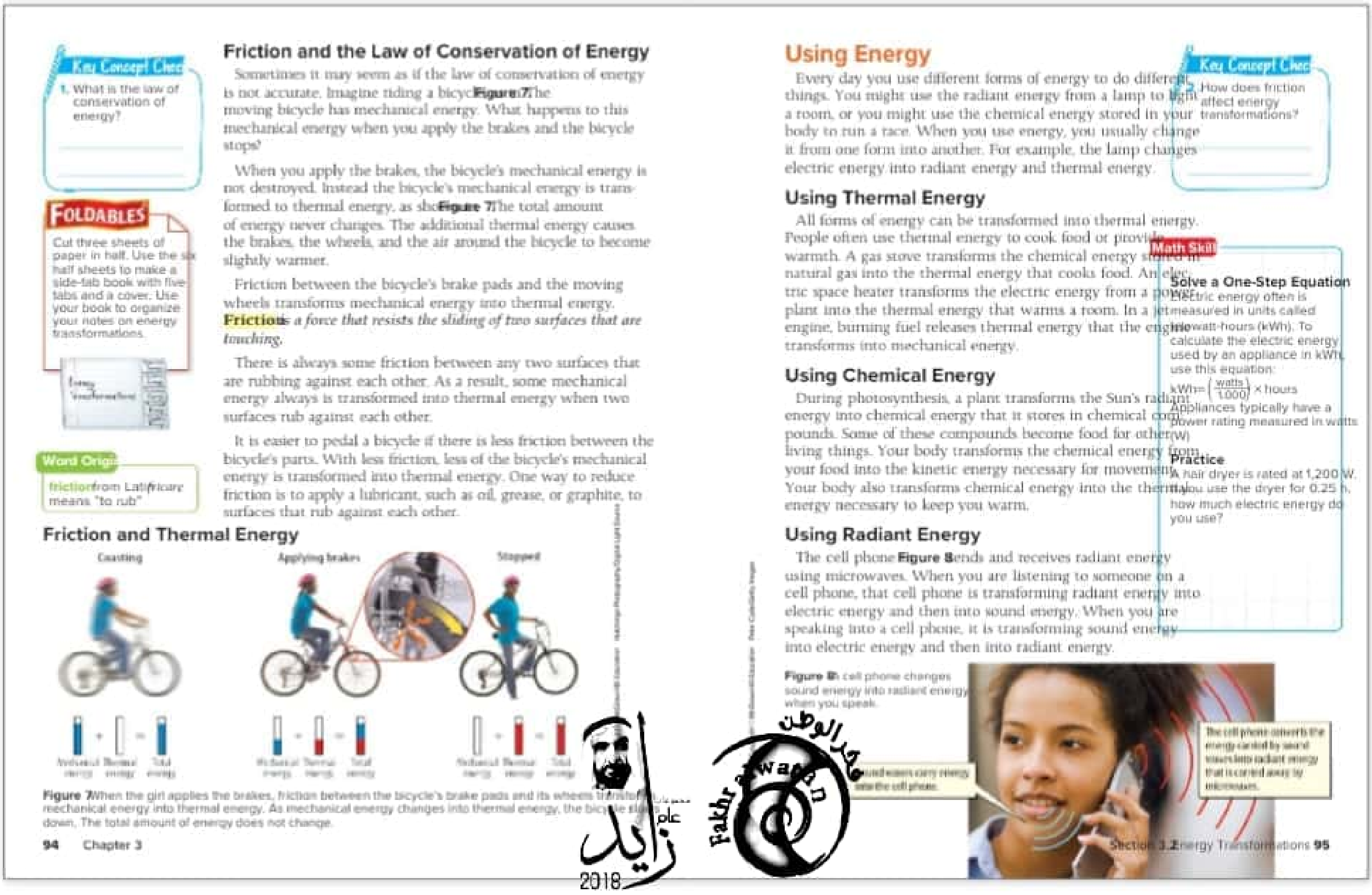
Ask: **What is this type of energy?** *It is thermal energy.*

3. Ask: **From where did this energy come?** *Friction between the rubbing hands transforms kinetic ener into thermal energy.*

Fun Fact

How do ice skates work? One argument is that friction between the skate's blade and the ice generates ther energy that melts the ice, which acts as a lubricant be the blade and the ice. However, this does not explain ice is slippery even if you're standing still. It is now kn that a microscopic layer of water forms on ice's surfac when it is below the melting point, without the aid of fr The colder the ice, the thinner the layer of water.

OL On Level AL Approaching Level BL Beyond Level



Key Concept Check
1. What is the law of conservation of energy?

FOLDABLES
Cut three sheets of paper in half. Use the six half sheets to make a side-tab book with five tabs and a cover. Use your book to organize your notes on energy transformations.

Word Origin
friction from Latin fricare, means "to rub"

Friction and the Law of Conservation of Energy

Sometimes it may seem as if the law of conservation of energy is not accurate. Imagine riding a bicycle, as in **Figure 7.** The moving bicycle has mechanical energy. What happens to this mechanical energy when you apply the brakes and the bicycle stops?

When you apply the brakes, the bicycle's mechanical energy is not destroyed. Instead the bicycle's mechanical energy is transformed to thermal energy, as shown in **Figure 7.** The total amount of energy never changes. The additional thermal energy causes the brakes, the wheels, and the air around the bicycle to become slightly warmer.

Friction between the bicycle's brake pads and the moving wheels transforms mechanical energy into thermal energy. **Friction** is *a force that resists the sliding of two surfaces that are touching.*

There is always some friction between any two surfaces that are rubbing against each other. As a result, some mechanical energy always is transformed into thermal energy when two surfaces rub against each other.

It is easier to pedal a bicycle if there is less friction between the bicycle's parts. With less friction, less of the bicycle's mechanical energy is transformed into thermal energy. One way to reduce friction is to apply a lubricant, such as oil, grease, or graphite, to surfaces that rub against each other.

Friction and Thermal Energy

Figure 7 When the girl applies the brakes, friction between the bicycle's brake pads and its wheels transforms mechanical energy into thermal energy. As mechanical energy changes into thermal energy, the bicycle slows down. The total amount of energy does not change.

Using Energy

Every day you use different forms of energy to do different things. You might use the radiant energy from a lamp to light a room, or you might use the chemical energy stored in your body to run a race. When you use energy, you usually change it from one form into another. For example, the lamp changes electric energy into radiant energy and thermal energy.

Key Concept Check
2. How does friction affect energy transformations?

Using Thermal Energy

All forms of energy can be transformed into thermal energy. People often use thermal energy to cook food or provide warmth. A gas stove transforms the chemical energy stored in natural gas into the thermal energy that cooks food. An electric space heater transforms the electric energy from a power plant into the thermal energy that warms a room. In a jet engine, burning fuel releases thermal energy that the engine transforms into mechanical energy.

Math Skills
Solve a One-Step Equation
Electric energy often is measured in units called kilowatt-hours (kWh). To calculate the electric energy used by an appliance in kWh, use this equation:
$kWh = \left(\frac{watts}{1,000}\right) \times hours$
Appliances typically have a power rating measured in watts (W).
Practice
A hair dryer is rated at 1,200 W. If you use the dryer for 0.25 h, how much electric energy do you use?

Using Chemical Energy

During photosynthesis, a plant transforms the Sun's radiant energy into chemical energy that it stores in chemical compounds. Some of these compounds become food for other living things. Your body transforms the chemical energy from your food into the kinetic energy necessary for movement. Your body also transforms chemical energy into the thermal energy necessary to keep you warm.

Using Radiant Energy

The cell phone in **Figure 8** sends and receives radiant energy using microwaves. When you are listening to someone on a cell phone, that cell phone is transforming radiant energy into electric energy and then into sound energy. When you are speaking into a cell phone, it is transforming sound energy into electric energy and then into radiant energy.

Figure 8 A cell phone changes sound energy into radiant energy when you speak.

Friction and the Law of Conservation of Energy

Students should understand the meaning of friction and that friction occurs between two surfaces moving in opposition; heat is the product of friction. Use the questions below to assess students' comprehension of these ideas.

Guiding Questions

AL What are some examples of friction creating thermal energy?	*Possible answers may include rubbing hands together to warm them, a rope burn, or striking a match.*
OL How does friction affect energy transformations?	*Friction transforms kinetic energy into thermal energy. A typical example is a bicycle brake rubbing against the rim of the wheel. The rim and the brake surface both become warm after the brake is applied.*
OL How is the total amount of energy in a bicycle affected as the friction in the bike chain and wheels cause the bike to slow and grow slightly warmer?	*As friction causes the bicycle to slow down, kinetic energy decreases while thermal energy increases. The total energy remains the same.*
BL If the contact area between two objects is getting warm, what might you conclude?	*Friction is producing thermal energy.*

Word Origin

friction

The Latin word *fricare* means "to rub" or "to chafe." Brainstorm how this Latin word became the root of the English word *friction.*

Ask: What is friction and what actions can create friction? *Friction is the resistance created when two surfaces touch each other. Have students focus more on the resistance created by rubbing their hands together and less on the heat that is created. Remember, thermal energy comes from friction, but they are not the same thing.*

Visual Literacy: Friction and Thermal Energy

Students who are not yet comfortable with the transformations of energy occurring all around us may need some extra help understanding where each type of energy comes from and where it goes. Help students understand that the energy is still there; it may just have a new name. Use the questions below to help students describe the role of friction in energy transformations and understand the role of friction in the three images that make up **Figure 7.**

Ask: What is happening to the speed of the bike in the second image? What evidence can you offer to support your answer? *The bicycle is slowing down because of the friction that is being applied to the bicycle wheels. This is shown by the decreasing kinetic energy graph and the increasing thermal energy graph.*

Ask: What happens to all the kinetic energy when the bike stops? *You can see what happens in the graph in the third picture. All the energy has transformed to thermal energy in the brakes and rims. Note that the thermal energy graph matches the total energy graph.*

Ask: What would happen to the speed of the bike if its moving parts were not well lubricated? How would the graph in the first picture change? *Students should understand that, in addition to the brakes, other parts of the bicycle can create friction that slows the speed. The pedals, gears, and chains can slow the bike. The graph would look more like the one under the middle picture.*

Using Energy

Use the reading and the Guiding Questions below to help students name the types of energy related to some of their daily activities.

Using Radiant Energy

Guiding Questions

AL What are examples of thermal energy that you used today?	*Possible answers: hot air to heat a house or classroom; hot water to cook; burning gasoline that powered the bus to school*
OL Why is thermal energy common?	*All forms of energy easily change to thermal energy.*

Using Chemical Energy

Guiding Questions

AL Where can people get the chemical potential energy stored by plants?	*Possible answers: from fruits, vegetables, bread, and other foods*
OL What are examples of how you transform food's chemical energy?	*Possible answers: to move, to keep warm*

Using Thermal Energy

Remind students of items that "radiate" energy, such as the Sun or the microwave oven **Figure 5**. Then have them read the section.

Ask: Compare and contrast different forms of radiant energy. *Some forms of radiant energy are visible, like the light from lamps or sunlight; some forms of radiant energy are invisible, like the microwaves and radio waves that we use to communicate. Radiant energy can travel long distances quickly.*

Math Skill

Solve a One-Step Equation

A one-step equation is an equation that can be solved in one step or action. If you plug in two parts of the equation, you can figure out the third part. This one-step equation assesses how much energy something will use over a period of time.

Practice

The hair dryer uses 0.3 kWh of electric energy. The one-step equation is written as follows:
kWh = 1,200/1,000 watts × 0.25 hours. Students should divide the number of watts by 1,000 to get 1.2 kW and then multiply that number by 0.25 hours to get 0.3 kWh.

Differentiated Instruction

AL Classroom Collage Bring in a dozen old magazines or newspapers, four poster boards, scissors and glue or ru cement. Hang the poster boards around the classroom. Label them *Using Thermal Energy, Using Chemical Ene Using Radiant Energy,* and *Using Electric Energy.* Instru students to look for images that show each type of ene being used. For example, a runner is using chemical en a washing machine is using electric energy, and a stove using thermal energy. As students find images have the create collages for each type of energy use.

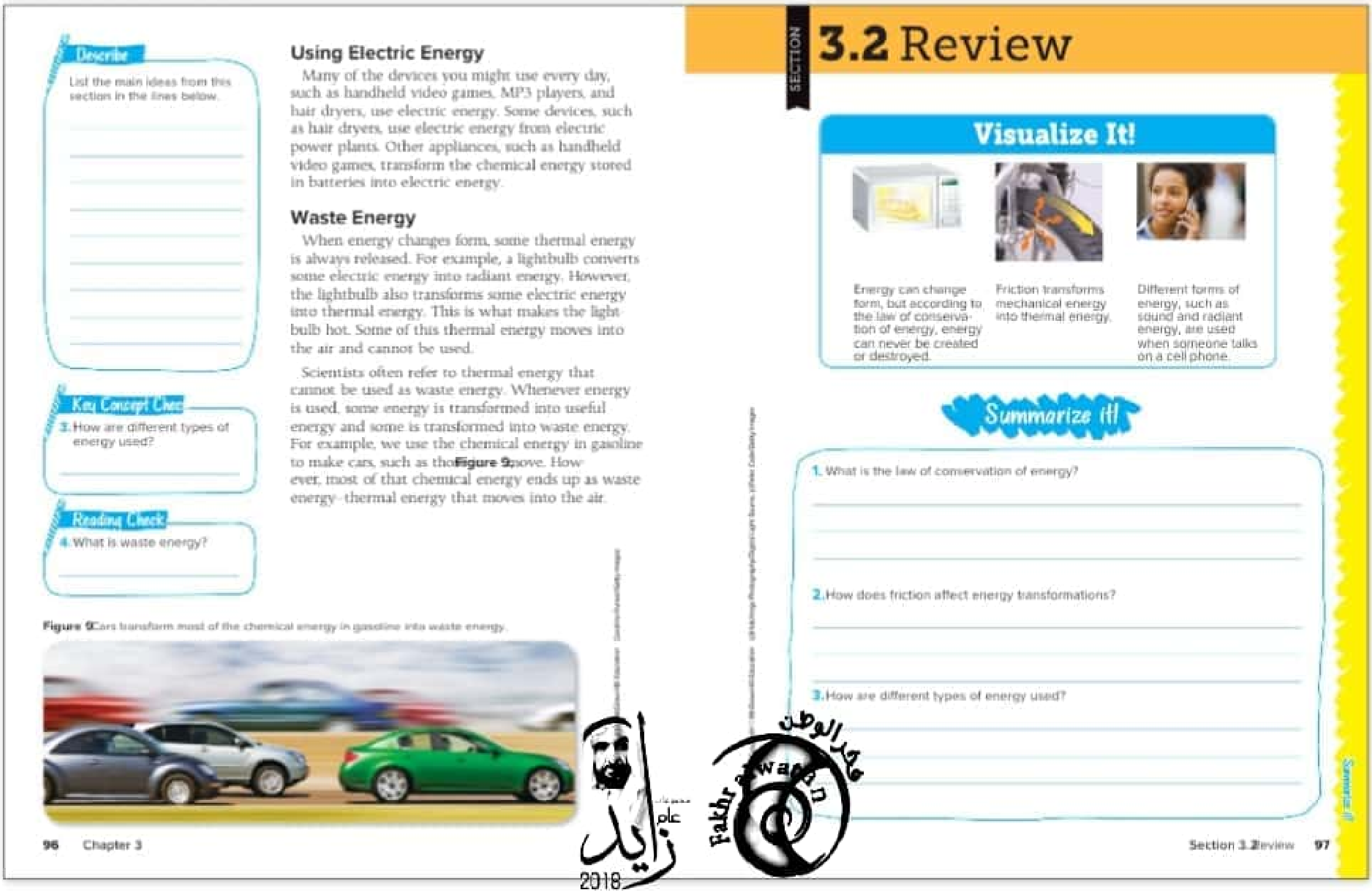
BL Conservation of Energy Have students create three different sets of flash cards. One set represents the diff forms of energy, another set represents the sources of energy, and the third set represents the users of energy Students can play a rummy game in which they try to g rid of cards by finding matched sets of form, source, an user cards.

Teacher Toolb

Teacher Demo
Jump Up and Down

1. Ask two volunteers to come to the front of the room
2. Explain to the class that humans are machines and, l all machines, we waste a lot of energy.
3. Ask the two volunteers how they fueled themselves t morning.
4. Have one of the volunteers begin to do a mild aerob exercise (e.g., jumping jacks, lifting textbooks up and down) while the other volunteer just watches.
5. After one minute of work, have a few other students estimate the temperature of the two volunteers' foreheads.
6. **Ask: What difference did you feel between the two volunteers? How do you explain that difference?** *The volunteer who worked was warmer. Some of the volunteer's energy was wasted as thermal energy.*

Fun Fact
Efficiency in Humans Almost 90 percent of a hiker's energy will be lost as waste thermal energy.



Describe

List the main ideas from this section in the lines below.

Using Electric Energy

Many of the devices you might use every day, such as handheld video games, MP3 players, and hair dryers, use electric energy. Some devices, such as hair dryers, use electric energy from electric power plants. Other appliances, such as handheld video games, transform the chemical energy stored in batteries into electric energy.

Waste Energy

When energy changes form, some thermal energy is always released. For example, a lightbulb converts some electric energy into radiant energy. However, the lightbulb also transforms some electric energy into thermal energy. This is what makes the light bulb hot. Some of this thermal energy moves into the air and cannot be used.

Scientists often refer to thermal energy that cannot be used as waste energy. Whenever energy is used, some energy is transformed into useful energy and some is transformed into waste energy. For example, we use the chemical energy in gasoline to make cars, such as thoFigure 9,above. However, most of that chemical energy ends up as waste energy–thermal energy that moves into the air.

Key Concept Check

3. How are different types of energy used?

Reading Check

4. What is waste energy?

Figure 9 Cars transform most of the chemical energy in gasoline into waste energy.

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SECTION **3.2** Review

Visualize It!

Energy can change form, but according to the law of conservation of energy, energy can never be created or destroyed.

Friction transforms mechanical energy into thermal energy.

Different forms of energy, such as sound and radiant energy, are used when someone talks on a cell phone.

Summarize It!

1. What is the law of conservation of energy?

2. How does friction affect energy transformations?

3. How are different types of energy used?

Section 3.2 Review 97

Using Electric Energy

Emphasize that electric energy is everywhere in our lives. Use events like power outages to remind students how much we depend on electric energy .

Guiding Questions

OL How are different types of energy used?	*Possible answer: in entertainment devices, to cook food, or to power vehicles*
BL Why are many devices that we use powered by electricity?	*Possible answer: Electric energy is safe, inexpensive, and easy to transport long distances.*

Waste Energy

Use these questions to remind students that energy can take a form that is useless to humans. Since every form of energy can change into thermal energy, it is the most common form of waste energy.

Guiding Questions

OL What is waste energy?	*Waste energy is energy that cannot be used.*
BL Can you think of waste energy that is not thermal waste?	*Sound energy often takes the form of waste energy. Jet engine noise is unusable. Light given off by the heating elements in a toaster is waste because it doesn't do anything useful.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize It!

Energy Transformations

Use Vocabulary

1. **Use the term** *friction* in a complete sentence.

Understand Key Concepts

2. **Explain** the law of conservation of energy in your own words.

3. **Describe** the energy transformations that occur when a piece of wood burns.

4. **Identify** the energy transformation that takes place when you apply the brakes on a bicycle.

5. Which energy transformation occurs in a toaster?
   - **A.** chemical to electric
   - **B.** electric to thermal
   - **C.** kinetic to chemical
   - **D.** thermal to potential

Interpret Graphics

6. **Organize Information** Fill in the graphic organizer below to show how kinetic and potential energy change when a ball is thrown straight up and then falls down.

Critical Thinking

7. **Judge** An advertisement states that a machine with moving parts will continue moving forever without having to add any energy. Can this be correct? Explain.

Math Skill

8. **Calculate** If you use a 1,000-W microwave for 0.15 h, how much electric energy do you use?

My Notes

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Section 3.2 Energy Transformations 99

Use Vocabulary

1. Sample answers: Friction made the bicycle stop rolling. Friction made the machine less efficient. **DOK 1**

Understand Key Concepts

2. Possible response: The law of conservation of energy states that energy cannot be created or destroyed. **DOK 1**

3. Chemical energy is transformed into radiant energy and thermal energy. **DOK 1**

4. Kinetic energy is transformed into thermal energy. **DOK 1**

5. B. electric to thermal **DOK 2**

Interpret Graphics

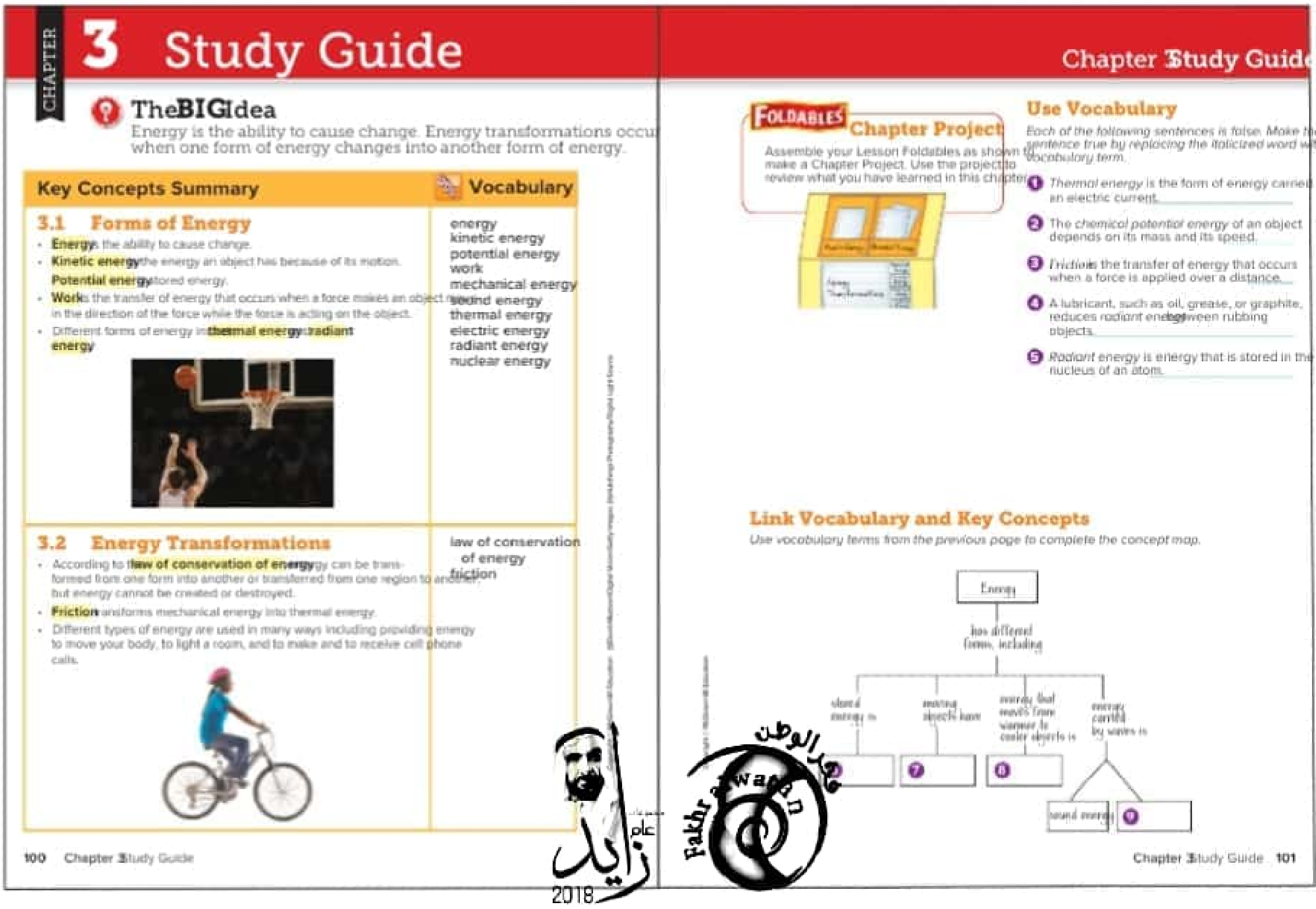
6. The ball has the most kinetic energy when it is first thrown. This kinetic energy transforms into potential energy as the ball rises. At the top of its path, all of the ball's kinetic energy has been transformed into potential energy. As the ball falls, potential energy transforms back into kinetic energy. Boxes show kinetic energy > potential energy > potential energy > kinetic energy **DOK 3**

Critical Thinking

7. The advertisement must be false. The machine would always release energy because of friction, and eventually all of its kinetic energy would be transformed into thermal energy, and would stop. **DOK 3**

Math Skill

8. $1000\ W \times 0.15\ h = 150\ Wh = 0.15\ kWh$ **DOK 2**



Key Concepts Summary

Study Strategy: Synthesis

One way to help students figure out if they understand Key Concepts is to have write them in their own words. Students should think about how they would explain these concepts to someone who has not read the text.

1. Ask students to draw a chart like the one below in their Science Journals, listing each Key Concept in the left column.
2. For each Key Concept, have them first put it in their own words. Then have them explain why the Key Concept is important.
3. After students have completed the chart, they can share their ideas with other students.

Example:

Key Concept	In My Own Words	Why It Is Important
Friction transforms mechanical energy into thermal energy.	When things are rubbed together it causes friction, which gives off a little heat.	Energy is never destroyed. It is always changed into another form of energy.

Vocabulary

Study Strategy: Meaning Match-Up

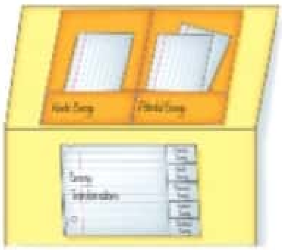
Have pairs of students create a match-up game. This activity allows students to build skills in word recognition and vocabulary.

1. Provide each pair of students with 12 index cards (six each). Then provide each pair with six vocabulary words from the Study Guide. Tell each student to write those words on six of the index cards, one word to a card. Then tell each student to write the definitions of those six words on the remaining cards, one definition per card.
2. Have students mix up the cards, turn them upside down, and place them in five rows of four cards each.
3. Player 1 turns over two cards. If the cards are a word and its matching definition, the player keeps the two cards and continues his or her turn. If the cards don't match, they are turned back over and Player 2 takes a turn. Continue until all the words are matched.

Example:

friction	a force that resists the sliding of surfaces two that are touching

FOLDABLES®



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

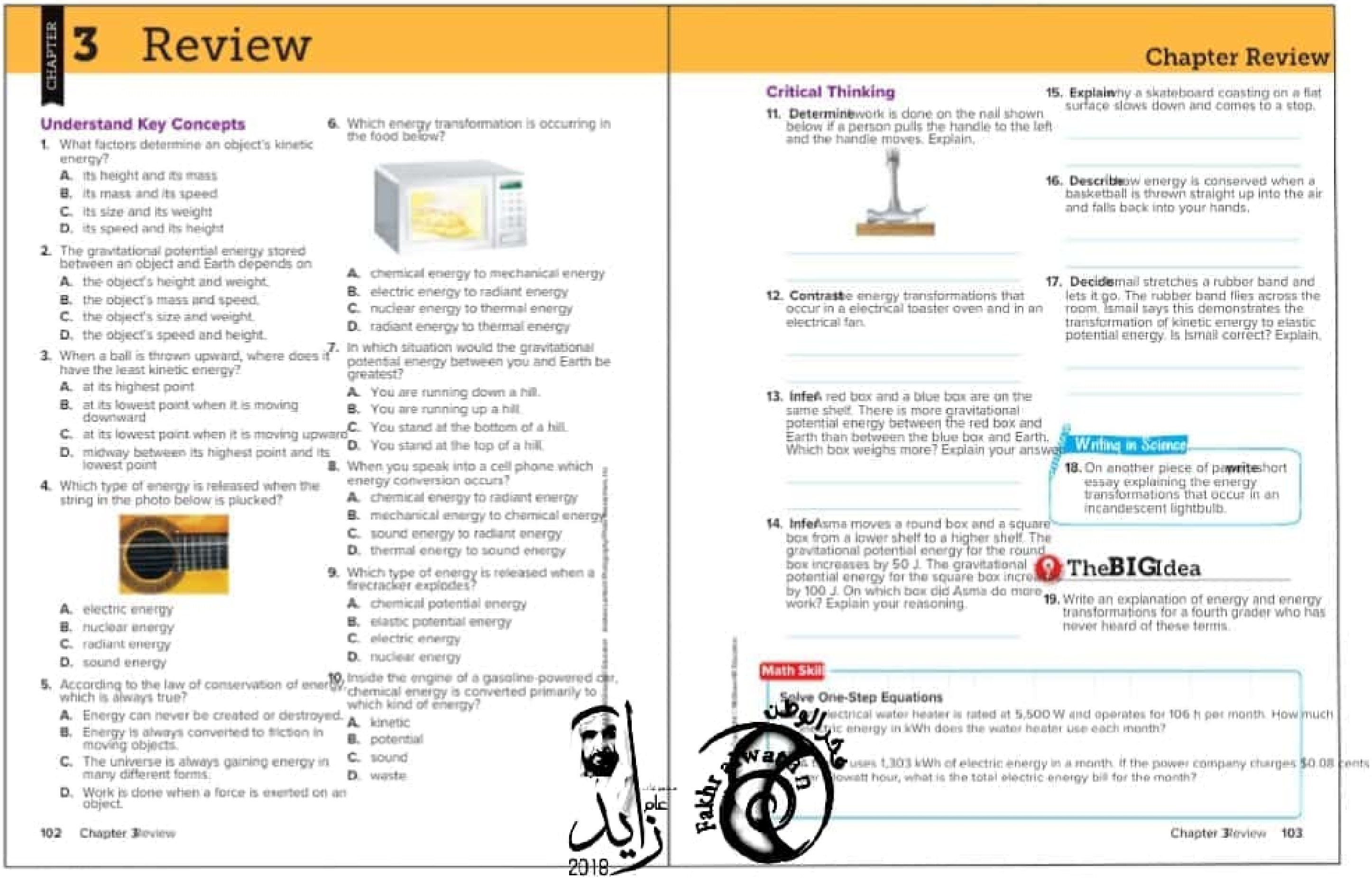
Use Vocabulary

1. electric energy
2. kinetic energy
3. work
4. friction
5. nuclear energy

Link Vocabulary and Key Concepts

6. potential energy
7. kinetic energy
8. thermal energy
9. radiant energy

Teacher Notes



CHAPTER 3 Review

Understand Key Concepts

1. What factors determine an object's kinetic energy?
A. its height and its mass
B. its mass and its speed
C. its size and its weight
D. its speed and its height

2. The gravitational potential energy stored between an object and Earth depends on
A. the object's height and weight.
B. the object's mass and speed.
C. the object's size and weight.
D. the object's speed and height.

3. When a ball is thrown upward, where does it have the least kinetic energy?
A. at its highest point
B. at its lowest point when it is moving downward
C. at its lowest point when it is moving upward
D. midway between its highest point and its lowest point

4. Which type of energy is released when the string in the photo below is plucked?
A. electric energy
B. nuclear energy
C. radiant energy
D. sound energy

5. According to the law of conservation of energy, which is always true?
A. Energy can never be created or destroyed.
B. Energy is always converted to friction in moving objects.
C. The universe is always gaining energy in many different forms.
D. Work is done when a force is exerted on an object.

6. Which energy transformation is occurring in the food below?
A. chemical energy to mechanical energy
B. electric energy to radiant energy
C. nuclear energy to thermal energy
D. radiant energy to thermal energy

7. In which situation would the gravitational potential energy between you and Earth be greatest?
A. You are running down a hill.
B. You are running up a hill.
C. You stand at the bottom of a hill.
D. You stand at the top of a hill.

8. When you speak into a cell phone which energy conversion occurs?
A. chemical energy to radiant energy
B. mechanical energy to chemical energy
C. sound energy to radiant energy
D. thermal energy to sound energy

9. Which type of energy is released when a firecracker explodes?
A. chemical potential energy
B. elastic potential energy
C. electric energy
D. nuclear energy

10. Inside the engine of a gasoline-powered car, chemical energy is converted primarily to which kind of energy?
A. kinetic
B. potential
C. sound
D. waste

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Chapter Review

Critical Thinking

11. Determine work is done on the nail shown below if a person pulls the handle to the left and the handle moves. Explain.

12. Contrast the energy transformations that occur in a electrical toaster oven and in an electrical fan.

13. Infer A red box and a blue box are on the same shelf. There is more gravitational potential energy between the red box and Earth than between the blue box and Earth. Which box weighs more? Explain your answer.

14. Infer Asma moves a round box and a square box from a lower shelf to a higher shelf. The gravitational potential energy for the round box increases by 50 J. The gravitational potential energy for the square box increases by 100 J. On which box did Asma do more work? Explain your reasoning.

15. Explain why a skateboard coasting on a flat surface slows down and comes to a stop.

16. Describe how energy is conserved when a basketball is thrown straight up into the air and falls back into your hands.

17. Decide Ismail stretches a rubber band and lets it go. The rubber band flies across the room. Ismail says this demonstrates the transformation of kinetic energy to elastic potential energy. Is Ismail correct? Explain.

Writing in Science

18. On another piece of paper, write a short essay explaining the energy transformations that occur in an incandescent lightbulb.

The BIG Idea

19. Write an explanation of energy and energy transformations for a fourth grader who has never heard of these terms.

Math Skill

Solve One-Step Equations

...electrical water heater is rated at 5,500 W and operates for 106 h per month. How much electric energy in kWh does the water heater use each month?

...uses 1,303 kWh of electric energy in a month. If the power company charges $0.08 cents ...kilowatt hour, what is the total electric energy bill for the month?

Chapter 3 Review 103

Understand Key Concepts

1 **B.** its mass and its speed
2 **A.** the object's height and weight.
3 **A.** at its highest point
4 **D.** sound energy
5 **A.** Energy can never be created or destroyed.
6 **D.** radiant energy to thermal energy
7 **D.** You stand at the top of a hill.
8 **C.** sound energy to radiant energy
9 **A.** chemical potential energy
10 **A.** kinetic

Critical Thinking

11 Work is done on the nail. A force is applied to the nail over a distance.

12 A toaster transforms electric energy into thermal energy. A fan transforms electric energy into kinetic energy and wastes thermal energy.

13 The red box weighs more. The gravitational potential energy between an object and Earth depends on the height and weight of the object. Both the red box and the blue box are at the same height.

14 Asma did more work on the square box. Asma transferred more energy to the square box.

15 Friction in the skateboard's wheels transforms kinetic energy into thermal energy.

16 The law of conservation of energy states that energy cannot be created or destroyed. Conserving energy means reducing the rate at which we transform energy into forms that are difficult or impossible to use.

17 Ismail has his order wrong. His example shows the transformation of elastic potential energy into kinetic energy.

Writing in Science

18 Answers will vary, but students should justify their reasoning. They should discuss electric, thermal, and radiant energy.

The BIG Idea

19 Answers will vary. All answers should include the ideas that energy is the ability to cause change, and that we can transform the energy in energy resources into other useful forms of energy.

Math Skills

Solve One-Step Equations

20. The water heater uses 583 kWh of electric energy each month.
5,500 W = 5.5 kW
5.5 kW × 106 h = 583 kWh

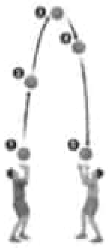
21. The electric bill for the month is $104.24.
1,303 kWh × $0.08/kWh = $104.24

Standardized Test Practice

Multiple Choice

1 Which is true when a player throws a basketball toward a hoop?
- A Kinetic energy is constant.
- B Potential energy is constant.
- C Work is done on the player.
- D Work is done on the ball.

Use the diagram below to answer questions 2 and 3.



2 At which points is the kinetic energy of the basketball greatest?
- A 1 and 5
- B 2 and 3
- C 2 and 4
- D 3 and 4

3 At which point is the gravitational potential energy at its maximum?
- A 1
- B 2
- C 3
- D 4

Use the table below to answer question 4.

Vehicle	Mass	Speed
Car 1	1,200 kg	20 m/s
Car 2	1,500 kg	20 m/s
Truck 1	4,800 kg	20 m/s
Truck 2	6,000 kg	20 m/s

4 Which vehicle has the most kinetic energy?
- A car 1
- B car 2
- C truck 1
- D truck 2

5 When you compress a spring, which type of energy increases?
- A kinetic
- B nuclear
- C potential
- D radiant

6 Sound energy cannot travel through
- A a vacuum.
- B a wooden table.
- C polluted air.
- D pond water.

7 A bicyclist uses brakes to slow from ... to a stop. What stops the bike?
- A friction
- B gravity
- C kinetic energy
- D thermal energy

Use the diagram below to answer question 8.

8 The work being done in the diagram above transfers energy to
- A the box.
- B the floor.
- C the girl.
- D the shelf.

9 Which is true of energy?
- A It cannot be created or destroyed.
- B It cannot change form.
- C Most forms cannot be conserved.
- D Most forms cannot be traced to a source.

10 Which energy transformation occurs when you light a gas burner?
- chemical to thermal
- electric to chemical
- nuclear to chemical
- radiant to thermal

Constructed Response

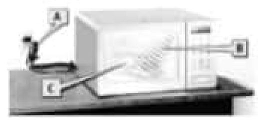
Use the table below to answer questions 11 and 12.

Form of Energy	Definition

11 In the above table, list six forms of energy. Briefly define each form.

12 Provide real-life examples of each of the listed forms of energy.

Use the diagram below to answer question 13.



13 Describe the energy transformations that occur at locations A, B, and C.

Need Extra Help?

If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12	13
Go to Section...	1	2	2	1	1	1	2	1	2	2	1	2	2

Multiple Choice

1 D—Correct. A, B, C—To move the ball through the air toward the hoop, the player must transfer energy to the ball. That is, the player must do work on the ball. Work is the transfer of energy that occurs when a force is applied over a distance. Neither force nor motion alone will cause an energy transfer; both are necessary. **DOK 1**

2 A—Correct. B, C, D—The diagram shows the trajectory of a ball as it is thrown between two players. The ball has the greatest kinetic energy as it leaves the first player's hand (point 1). As the ball moves toward the highest point in its path, kinetic energy is transformed into gravitational potential energy. As the ball falls, gravitational potential energy is transformed back into kinetic energy. When the ball reaches the second player (point 5), its kinetic energy is again at its greatest. **DOK 2**

3 C—Correct. A, B, D—The gravitational potential energy is a function of the ball's height. When the ball is at the highest point in its path (point 3), the gravitational potential energy is greatest. **DOK 2**

4 D—Correct. A, B, C—An object's kinetic energy is a function of that object's mass and speed. As speed and/or mass increases, kinetic energy increases. Because all objects listed in the table are moving at the same speed (20 m/s), the object with the greatest mass (truck 2) has the greatest kinetic energy. **DOK 2**

5 C—Correct. A—A compressed spring is not moving so it does not have kinetic energy. B, D—Nuclear and radiant energy are not part of a compressed spring. **DOK 1**

6 A—Correct. B, C, D—Sound is a mechanical wave and can only travel through matter. A vacuum does not contain any matter; therefore, sound cannot travel through it. **DOK 1**

7 A—Correct. B, C, D—When a bicyclist applies the brakes, brake pads rub against the wheels, which produces friction. Friction transforms kinetic energy into thermal energy. The bike slows as it loses kinetic energy. **DOK 1**

8 A—Correct. B, C, D—The diagram shows a girl doing work on a box; she is applying a force to the box over a distance. This results in the girl transferring energy from herself to the box. **DOK 2**

9 A—Correct. B, C, D—Although energy can be transformed from one form to another or transferred from one region to another, energy cannot be created or destroyed. This principle is known as the law of conservation of energy. **DOK 1**

10 A—Correct. B, C, D—Gas does not have potential nuclear, electric, or radiant energy. **DOK 1**

Constructed Response

11 Answers may vary slightly. Possible answers:

Form of Energy	Definition
Mechanical	the sum of the kinetic energy and potential energy of an object
Sound	energy from vibrating objects carried by sound waves
Thermal	energy due to the motions of particles that make up an object
Electric	energy that an electric current carries
Radiant (Light)	energy that electromagnetic waves carry
Nuclear	energy stored in the nucleus of an atom

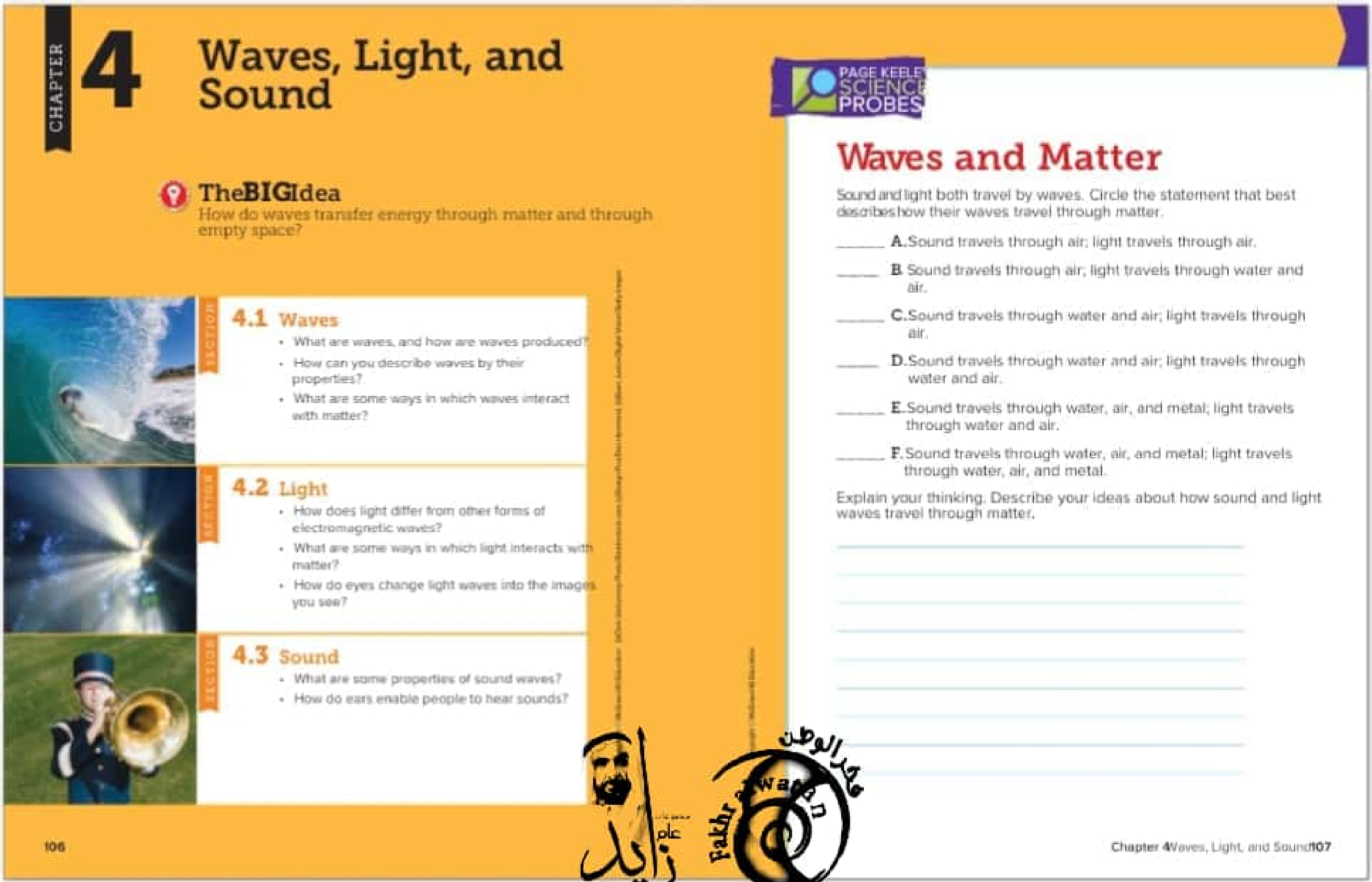
DOK 1

12 Answers will vary. Possible answers: mechanical energy—moving pedals drive bicycle wheels; sound energy—vibrating violin strings produce music; thermal energy—a hot oven; electric energy—you can turn on a lamp when the lamp is plugged in; radiant (light) energy—microwave energy cooking a frozen dinner; nuclear energy—nuclear reactors heating water to steam, which powers generators for electricity. **DOK 3**

13 At location A, electric energy is not transformed but it is transferred from the outlet to the microwave. At location B, electric energy is transformed into radiant energy. At location C, radiant energy is transformed into thermal energy. **DOK 2**

Answer Key

Question	Answer
1	D
2	A
3	C
4	D
5	C
6	A
7	A
8	A
9	A
10	A
11	See extended answer.
12	See extended answer.
13	See extended answer.



CHAPTER 4

Waves, Light, and Sound

TheBIGIdea
How do waves transfer energy through matter and through empty space?

4.1 Waves
- What are waves, and how are waves produced?
- How can you describe waves by their properties?
- What are some ways in which waves interact with matter?

4.2 Light
- How does light differ from other forms of electromagnetic waves?
- What are some ways in which light interacts with matter?
- How do eyes change light waves into the images you see?

4.3 Sound
- What are some properties of sound waves?
- How do ears enable people to hear sounds?

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PAGE KEELEY SCIENCE PROBES

Waves and Matter

Sound and light both travel by waves. Circle the statement that best describes how their waves travel through matter.

_____ A. Sound travels through air; light travels through air.

_____ B. Sound travels through air; light travels through water and air.

_____ C. Sound travels through water and air; light travels through air.

_____ D. Sound travels through water and air; light travels through water and air.

_____ E. Sound travels through water, air, and metal; light travels through water and air.

_____ F. Sound travels through water, air, and metal; light travels through water, air, and metal.

Explain your thinking. Describe your ideas about how sound and light waves travel through matter.

Chapter 4 Waves, Light, and Sound 107

Waves, Light, and Sound

TheBIGIdea

There are no right or wrong answers to these questions. Write studentgenerated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL Describe a water wave you have seen.	*Students may describe a large wave rolling across an ocean or a lake, smaller waves in a pond or swimming pool, ripples in a pool of rainwater, a bathtub, or sink.*
OL Describe one property of a wave.	*Students may describe the size, speed, or height of a wave, or the amount of energy it carries.*
BL Think about water waves of varying sizes on a lake or in a swimming pool. Describe one way in which waves of varying sizes are the same and one way in which they're different.	*Students may describe how larger waves affect boats and other objects in the water as compared to smaller waves, which often have little effect. No matter the size, all water waves transfer energy as they move across the surface of the water.*

PAGE KEELEY SCIENCE PROBES

Waves and Matter

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Use the photo to start a discussion that connects students to The Big Idea. To focus the discussion, ask the class the questions below.

TIP List Related Terms Ask students to brainstorm a list of terms they already know that relate to waves, light, and sound. For example, students might list words such as *brightness* or *energy*. Write the list on chart paper or on the board. As the class reads the chapter, add new terms based on what they learn.

Guiding Questions

AL What do the different colors on the map mean?	*Varying colors are used on maps to show differing degrees of precipitation.*
OL How do meteorologists get the information they display on a weather map?	*Weather satellites capture images that meteorologists rely on to predict weather patterns and climate.*
BL How do waves transfer energy through matter and through empty space?	*Energy creates disturbances that transfer the energy in waves through matter and space.*

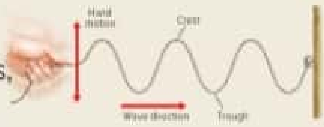
Science Content Background

Lesson 1

Waves

What are waves? A wave is a disturbance that transfers energy. As a wave moves outward from its origin, particles push and pull against each other in a medium and move energy from one place to another. However, waves do not transfer matter.

Different Types of Waves Vibrating particles produce mechanical waves, including water waves, seismic waves, and sound waves, which can travel only through matter. Mechanical waves can be either transverse or longitudinal. Vibrating charged particles produce electromagnetic waves, including visible light waves, radio waves, and microwaves, which can travel through matter and a vacuum, such as space.



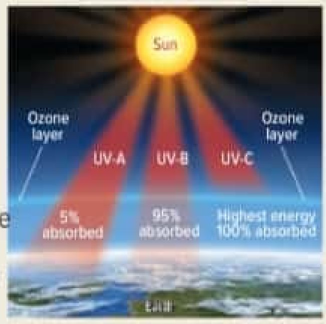
Properties of Waves Wavelength is the distance from a specific point on a wave to the same point on the next wave. Frequency, measured in hertz, is the number of wavelengths that pass by a certain point each second. A wave's speed is affected by both the wave's type and the medium through which it travels. The larger the amplitude of a wave, the more energy it carries.

How Waves Interact with Matter Transmission occurs when a wave passes through a material. In absorption, a wave transfers its energy to a material. Reflection occurs when a wave bounces off the surface of a material. The angle between the normal (an imaginary line perpendicular to a surface) and the incoming wave equals the angle between the normal and the reflected wave. Refraction occurs when a wave changes speed as it moves from one material to another. Diffraction occurs when an object blocks the path of a wave and causes it to change direction.

Lesson 2

Light

What are light waves? Electromagnetic waves can travel through matter and the vacuum of space. Electromagnetic waves include radio waves, microwaves, infrared waves, ultraviolet waves, X-rays, and gamma rays.



How Light Interacts with Matter The interactions of light waves with matter affect what we see. Matter can transmit, absorb, and reflect light waves. Transmission occurs when light waves pass through transparent or translucent materials. Absorption occurs when opaque materials block light waves. Reflection occurs when light waves bounce off surfaces.

The Properties of Light Light travels at a speed of 300,000 km/s through empty space. Visible light includes all colors that humans can see. The color violet has the shortest wavelength and red has the longest. Intensity is the amount of energy that passes through a square meter of space in a second. The greater the energy of a wave, the higher its intensity

How Eyes "See" Eyes convert light into electrical signals. These signals are transmitted instantly to the brain, which "sees" them as images. The human eye includes the cornea, which refracts light, the lens, which focuses light waves, and the retina, which absorbs light and sends signals to the brain via the optic nerve.

Lesson 3

Sound

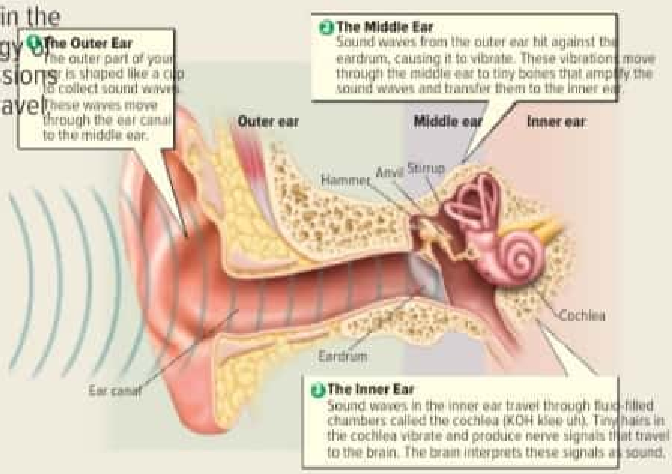
What are sound waves? Sound also travels in waves. Sound waves are mechanical waves and must travel through matter. Sound waves are longitudinal waves in which the particles in the material travel in the same direction as the wave. The energy of sound waves comes from vibrations, which create compressions and rarefactions in the medium through which the waves travel.

Table 3 The Speed of Sound

Material	Speed (m/s)
Air (0°C)	331
Air (20°C)	343
Water (20°C)	1,481
Water (0°C)	1,500
Seawater (25°C)	1,533
Ice (0°C)	3,500
Iron	5,130
Glass	5,640

The Properties of Sound The compressions and rarefactions of a sound wave determine its properties. Properties of sound waves include pitch, speed, and intensity, among others. Pitch is how high or low a sound is. The higher the frequency of the wave is, the higher the pitch of the sound.

How Ears “Hear” Our ears transform sound waves into electrical signals that the brain interprets. Sound enters through the outer ear. The middle ear increases the intensity of the waves and the inner ear converts the waves to signals that are transmitted to the brain via the auditory nerve.



Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* Light travels and tends to maintain its direction of motion until it interacts with an object or material. Light can be absorbed, redirected, bounced back, or allowed to pass through.

* The brain gets signals from all parts of the body telling it what is going on there. The brain also sends signals to parts of the body to influence what they do.

* Something can be "seen" when light waves emitted or reflected by it enter the eye—just as something can be "heard" when sound waves from it enter the ear.

* Things that make sound vibrate.

* How fast things move differ greatly.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

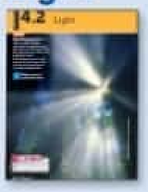
Lesson 1 Waves

1 Waves are disturbances that transfer energy from place to place. A mechanical wave forms when a source of energy causes particles of matter to vibrate. A vibrating electric charge produces an electromagnetic wave.

2 You can describe wavelength, frequency, speed, amplitude, and energy of waves.

3 Matter can transmit, absorb, or reflect a wave. It also can change a wave's direction by refraction or diffraction.

Lesson 2 Light



4 Light differs from other forms of electromagnetic waves by its frequency, wavelength, and energy. Light is the type of electromagnetic wave that is visible with the human eye.

5 Matter can transmit, absorb, and reflect light. These interactions differ in how much light the matter transmits and how much it changes the direction of light.

6 Cells in the retina of the eyes change light into electric signals that travel to the brain.

Lesson 3 Sound

7 Sound waves travel through matter as a series of compressions and rarefactions. The frequency and wavelength of a sound wave determines the pitch. Sound waves with greater amplitude sound louder.

8 Ears collect and amplify sound and then convert it to signals the brain can interpret.

Different Speeds through Different Mediums

Find Out What Students Think

Students may think that...

... waves travel at the same speed through solids, liquids, and gases. They may not understand that waves move at different speeds through different mediums. Refraction is a change in direction that occurs when a wave changes speed as it moves from one medium to another.

Discussion

Pass a photo around for students to observe of a person standing in the shallow end of a swimming pool or any pool of water. **Ask:** How do the legs appear in the photo? **They seem to bend or ripple.** **Ask:** How does the image of the legs compare to their actual position? **The image is distorted and at an angle compared to the actual position.** **Ask:** The light waves changed direction, which causes this change in appearance. Waves change direction when they strike a smooth surface or move around an object. What else causes waves to change direction? **A change in speed also causes waves to change direction.** **Ask:** How are the particles in water different from the particles in air? **Water is a liquid and air is a gas. So, the particles in water are closer together, move more slowly, and collide less often than the particles in air.** Light waves travel at a slower speed through water than through air, which makes your legs appear to bend and ripple.

Promote Understanding

Activity Have students work in pairs. Provide each pair with an opaque bowl, a 1-fils coin, a glass of water, and tape. The amount of water in the glass should be enough to fill the bowl.

1. Have students tape the 1-fils coin to the bottom of the bowl.
2. Have students place the bowl on a flat surface. One student should slowly step away from the bowl until he or she can no longer see the 1-fils coin on the bottom. Then the student should stop moving and remain in place.
3. The other student should pour water very slowly into the bowl. The student should keep pouring water until his or her partner can see the 1-fils coin appear on the bottom.
4. Have students switch places and repeat the experiment. Then ask them to record their observations in their Science Journals.
5. Explain that when the bowl is empty and you step away from it, you cannot see the 1-fils coin because the light waves do not reach your eyes. However, when you pour water into the bowl, light waves change speed as they travel through the liquid. The light waves change direction, which enables you to see the 1-fils coin.

Solutions

Find Out What Students Think

Students may think that...

... pitch helps explain how loud or soft a sound is. They may believe that loudness and pitch are directly related and not realize that they are independent properties of sound waves.

Discussion

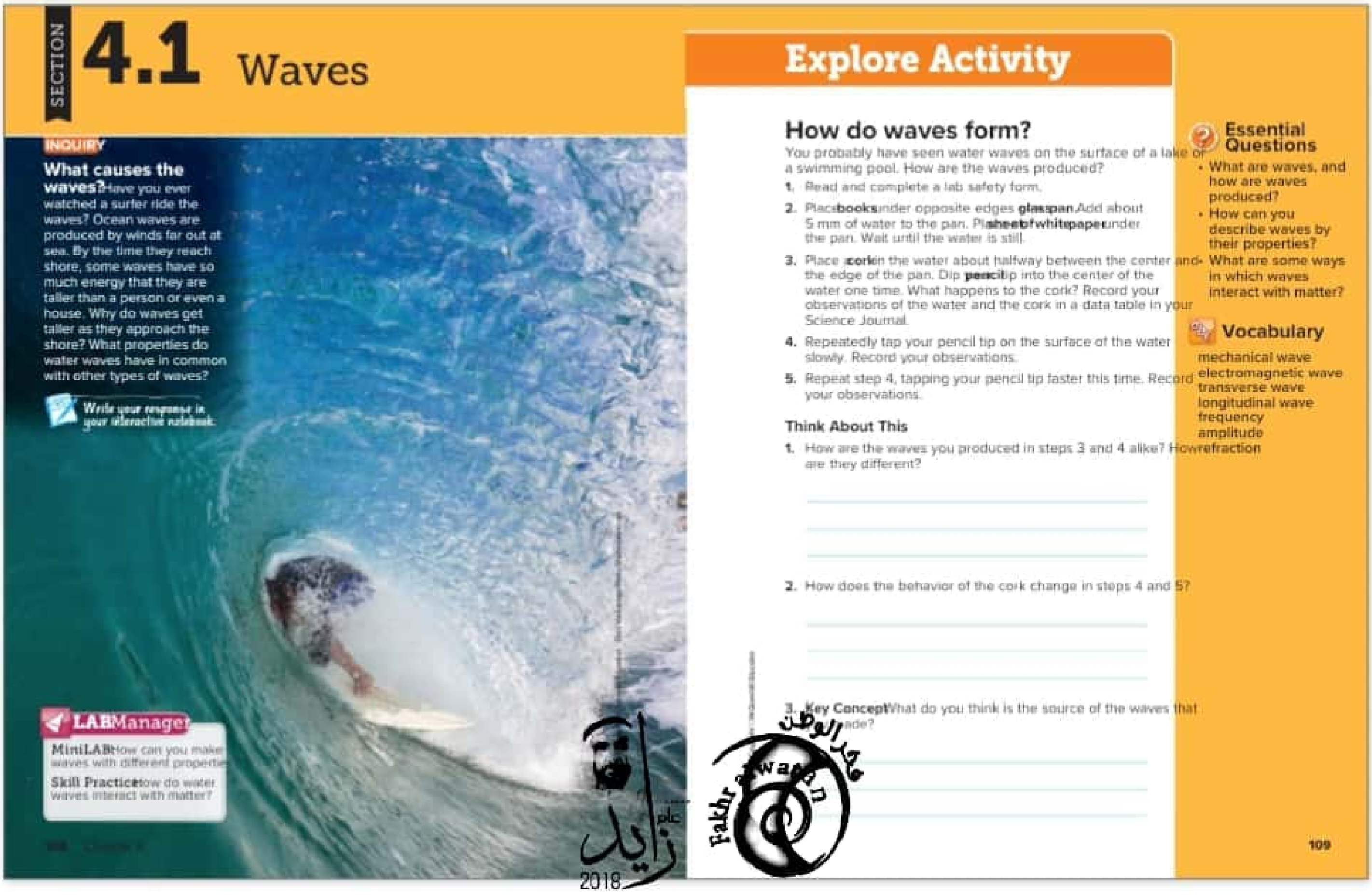
Ask: What is pitch? **Pitch is how high or low a sound is.** **Ask:** How does changing the frequency change the pitch? **Sounds at higher frequencies have higher pitches. Sounds at lower frequencies have lower pitches.** **Ask:** Loudness is how your ear perceives the intensity of a sound. What is the definition of intensity? **Intensity is the amount of energy that passes through a square meter of space in one second.** **Ask:** How can you change the intensity of a sound wave? **You can change the amount of energy that flows through it or move closer to or farther from the source of the sound.** **Ask:** Would changing the amount of energy or moving closer to or farther from the source also change the frequency of the wave? **No, the frequency would remain the same. To change the frequency, you would need to change the wavelength.** **Ask:** So, does changing the frequency and pitch of a sound wave also change its loudness or intensity? **No**

Promote Understanding

Activity Provide each student with 3 or 4 empty soda bottles of different sizes, a beaker, and water.

1. Have each student add 100 mL of water to the first bottle, 200 mL to the second bottle, and so on.
2. Have students blow with the same amount of force across the top of each bottle to produce a sound. Have students listen carefully to each sound and describe it in his or her Science Journal. Students should notice that, although the loudness remains the same, the pitch increases as the water level increases.
3. Explain that the vibrating air in each bottle produces the sound. As the water level increases, the amount of air in the beaker decreases. The shorter column of air results in sound waves with a higher frequency and a higher pitch.
4. Have students blow across the top of each bottle again, a little more forcefully this time, and record their observations.
5. The sounds they produce will be louder, because the amount of force has changed, but the pitch will only change as a result of the change in water level.

PAGE KEELEY SCIENCE PROBES


SECTION 4.1 Waves

INQUIRY

What causes the waves? Have you ever watched a surfer ride the waves? Ocean waves are produced by winds far out at sea. By the time they reach shore, some waves have so much energy that they are taller than a person or even a house. Why do waves get taller as they approach the shore? What properties do water waves have in common with other types of waves?

Write your response in your interactive notebook.

LABManager

MiniLAB How can you make waves with different properties?

Skill Practice How do water waves interact with matter?

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Explore Activity

How do waves form?

You probably have seen water waves on the surface of a lake or a swimming pool. How are the waves produced?

1. Read and complete a lab safety form.
2. Place **books** under opposite edges of a **glass pan**. Add about 5 mm of water to the pan. Place a **sheet of white paper** under the pan. Wait until the water is still.
3. Place a **cork** in the water about halfway between the center and the edge of the pan. Dip a **pencil** tip into the center of the water one time. What happens to the cork? Record your observations of the water and the cork in a data table in your Science Journal.
4. Repeatedly tap your pencil tip on the surface of the water slowly. Record your observations.
5. Repeat step 4, tapping your pencil tip faster this time. Record your observations.

Think About This

1. How are the waves you produced in steps 3 and 4 alike? How are they different?
2. How does the behavior of the cork change in steps 4 and 5?
3. **Key Concept** What do you think is the source of the waves that you made?

Essential Questions
- What are waves, and how are waves produced?
- How can you describe waves by their properties?
- What are some ways in which waves interact with matter?

Vocabulary
mechanical wave
electromagnetic wave
transverse wave
longitudinal wave
frequency
amplitude
refraction

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INQUIRY

About the Photo **What causes the waves?** Ask students to describe the waves in this photo. Discuss how the waves travel across the surface of the water.

Guiding Questions

AL How does it feel when a wave flows past you?	*Waves push against you and make you bounce up and down in the water.*
OL Waves make objects rise and fall in the water. Why do you think that happens?	*Waves have a lot of energy and can make things move.*
BL How do you think the waves affect people and objects in the water?	*As the waves pass, they affect the motion of the people and objects in the water.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Create Wave Trading Cards

1. Give one index card to each student. Assign each student a number from 1 to 4. Then tell students to draw a picture of a different kind of wave according to the assigned number:
   1. Graw a picture of what happens to pond water when a pebble is tossed into it.
   2. Draw a picture of a rainbow created by a prism.
   3. Draw a picture of wind pushing a sailboat.
   4. Draw a picture of ocean waves reaching a rocky shore.
2. Have students look at the four vocabulary terms that end with *wave*. **Ask:** **Which term best describes your illustration?** **Explain** *Students should write their answers on the backs of their cards.*
3. Instruct students to refer to their index cards as they read this lesson, and to raise their hands when they read the section that explains the type of wave they illustrated.

Explore Activity

How do waves form?

Teacher Notes

Purpose
The students will understand that energy causes waves. Changing the energy transferred to a medium changes the properties of the wave.

Materials
two textbooks, glass pan, sheet of white paper, cork, pencil
Alternative materials: cork sliced into a disc about 1 cm thick, fishing bobber, or plastic bottle top

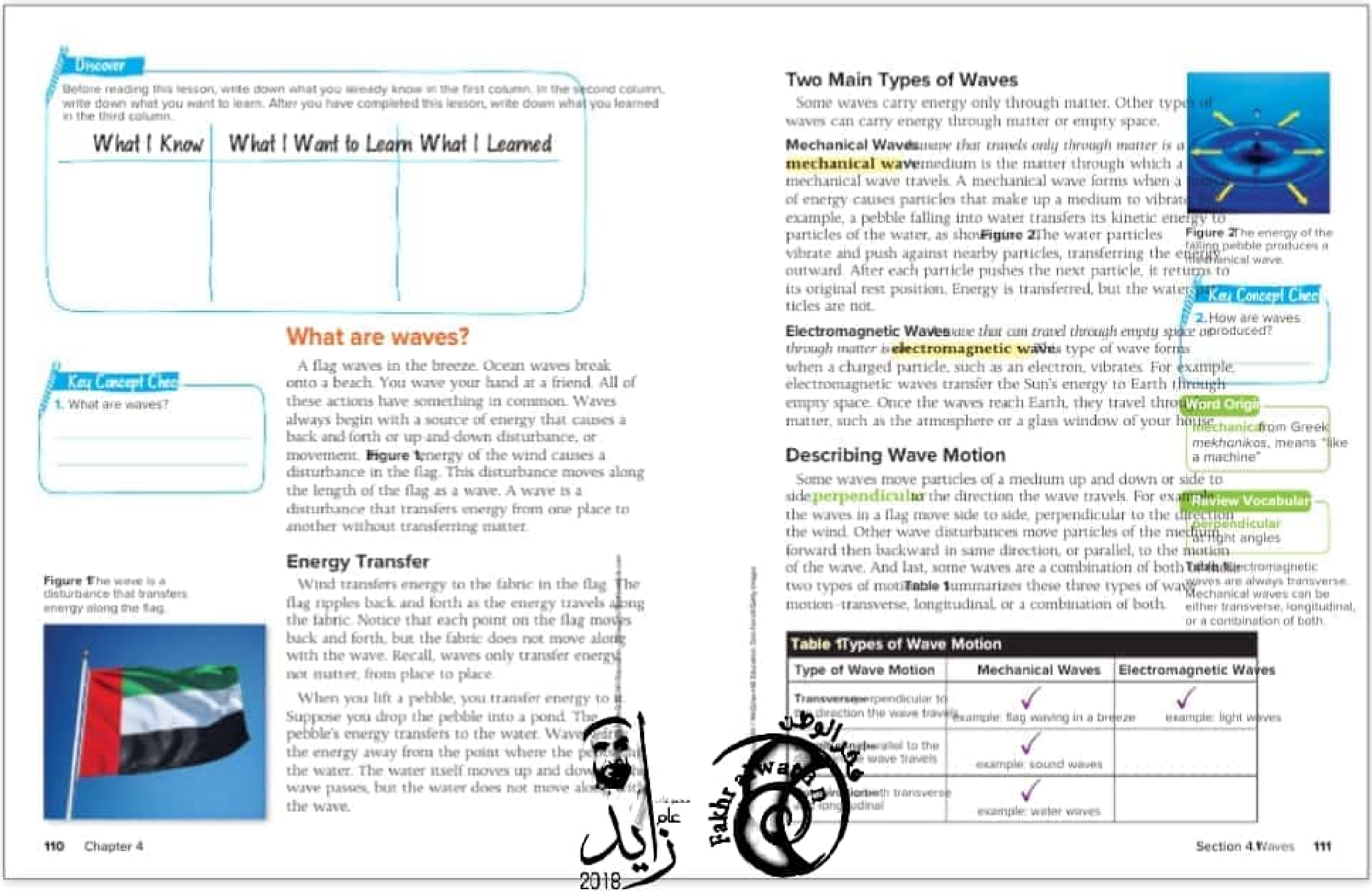
Before You Begin
Have students brainstorm different waves they have seen (such as waves on a flag, ocean waves, or waves at a stadium) and then think about what causes these waves.

Guide the Investigation
- A drop of liquid dish soap or food coloring in the water decreases surface tension and makes the waves easier to see.
- The cork might move to the edge of the pan. Have students think about how energy is transferred to the cork and what that might do to the cork's motion.

Sample Data Table

Procedure	Behavior of water	Behavior of cork
Tap one time	Concentric circles moved to edge, bounced off, and stopped.	Bobbed, then stopped moving
Slowly tap	Continuous concentric circles	Bobbed back and forth each time a wave went under it
Quickly tap	Continuous concentric circles closer together	Bobbed back and forth each time a wave went under it

Think About This
1. The waves were circular and spread out from the pencil tip in all directions with equal speed. Step 3 produced a wave that traveled to the edges and bounced off the sides of the pan, but the water became still very quickly. Step 4 produced repeated circular waves throughout the pan.
2. In step 4 the cork wobbled a couple of times, then stopped moving. In step 5, the cork wobbled back and forth repeatedly.
3. **Key Concept** The energy from the pencil tip caused all the waves.



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Key Concept Check

1. What are waves?

What are waves?

A flag waves in the breeze. Ocean waves break onto a beach. You wave your hand at a friend. All of these actions have something in common. Waves always begin with a source of energy that causes a back-and-forth or up-and-down disturbance, or movement. In **Figure 1**, energy of the wind causes a disturbance in the flag. This disturbance moves along the length of the flag as a wave. A wave is a disturbance that transfers energy from one place to another without transferring matter.

Energy Transfer

Wind transfers energy to the fabric in the flag. The flag ripples back and forth as the energy travels along the fabric. Notice that each point on the flag moves back and forth, but the fabric does not move along with the wave. Recall, waves only transfer energy, not matter, from place to place.

When you lift a pebble, you transfer energy to it. Suppose you drop the pebble into a pond. The pebble's energy transfers to the water. Waves carry the energy away from the point where the pebble hit the water. The water itself moves up and down as the wave passes, but the water does not move along with the wave.

Figure 1 The wave is a disturbance that transfers energy along the flag.

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Two Main Types of Waves

Some waves carry energy only through matter. Other types of waves can carry energy through matter or empty space.

Mechanical Waves *A wave that travels only through matter is a* **mechanical wave**. A medium is the matter through which a mechanical wave travels. A mechanical wave forms when a source of energy causes particles that make up a medium to vibrate. For example, a pebble falling into water transfers its kinetic energy to particles of the water, as shown in **Figure 2**. The water particles vibrate and push against nearby particles, transferring the energy outward. After each particle pushes the next particle, it returns to its original rest position. Energy is transferred, but the water particles are not.

Figure 2 The energy of the falling pebble produces a mechanical wave.

Key Concept Check

2. How are waves produced?

Electromagnetic Waves *A wave that can travel through empty space or through matter is an* **electromagnetic wave**. This type of wave forms when a charged particle, such as an electron, vibrates. For example, electromagnetic waves transfer the Sun's energy to Earth through empty space. Once the waves reach Earth, they travel through matter, such as the atmosphere or a glass window of your house.

Word Origin

mechanical from Greek *mekhanikos*, means "like a machine"

Describing Wave Motion

Some waves move particles of a medium up and down or side to side, **perpendicular** to the direction the wave travels. For example, the waves in a flag move side to side, perpendicular to the direction of the wind. Other wave disturbances move particles of the medium forward then backward in same direction, or parallel, to the motion of the wave. And last, some waves are a combination of both of these two types of motion. **Table 1** summarizes these three types of wave motion—transverse, longitudinal, or a combination of both.

Review Vocabulary

perpendicular at right angles

Table 1 Electromagnetic waves are always transverse. Mechanical waves can be either transverse, longitudinal, or a combination of both.

Table 1 Types of Wave Motion

Type of Wave Motion	Mechanical Waves	Electromagnetic Waves
Transverse perpendicular to the direction the wave travels	✓ example: flag waving in a breeze	✓ example: light waves
Longitudinal parallel to the direction the wave travels	✓ example: sound waves	
Combination both transverse and longitudinal	✓ example: water waves	

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What are waves?

Ask students to describe the waves that ripple through the flag in **Figure 1**. Then have students read the first paragraph on the page and answer these questions.

Guiding Questions

OL What are waves?	*Waves are disturbances that transfer energy from one place to another without transferring matter.*
BL How does a wave affect energy and matter?	*A wave moves energy from one place to another. A wave moves through matter but does not move it.*

Energy Transfer

Have students discuss their experience in the **Launch Lab** and describe how the cork moved in the glass pan when they created waves. Review the definition of energy; then have students read the section.

Two Main Types of Waves

Explain the two types of waves. Water waves and the waves in the flag in **Figure 1** are examples of one type. Light waves from a candle or a lamp are examples of another type. Have students read the first three paragraphs and **Figure 2**.

Guiding Questions

AL What is a mechanical wave? What is an electromagnetic wave?	*A mechanical wave is a wave that can travel only through matter. An electromagnetic wave can travel through matter or through empty space.*
OL How are waves produced?	*Mechanical waves are produced when a source of energy causes particles of matter to vibrate. Electromagnetic waves are produced when a source of energy causes a charged particle to vibrate.*
BL What are two ways that the energy of a mechanical wave differs from the energy of an electromagnetic wave?	*The energy of a mechanical wave causes particles to vibrate and can move only through matter. The energy of an electromagnetic wave causes charged particles to vibrate and travel through matter or empty space.*

WORD ORIGIN

mechanical

Have students compare modern uses for the term *mechanical*, such as in relation to a machine or as a type of energy, to its Greek origin.

Describing Wave Motion

Have students read the last paragraph, and then compare the types of waves described in **Table 1**. Explain that different types of waves move in different ways. Then ask these questions.

Guiding Questions

OL Which kind of wave moves back and forth? Give an example.	*a longitudinal wave; a sound wave*
BL What kind of wave moves both back and forth and up and down? Give an example.	*a wave that is a combination of transverse and longitudinal; a water wave*

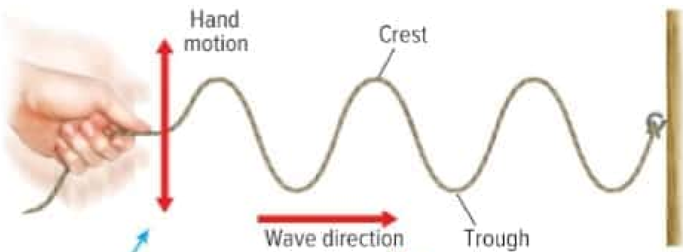
Review Vocabulary

perpendicular

Have students review the definition of the word *perpendicular*. Draw perpendicular lines on chart paper. Explain that the lines are perpendicular because when they intersect they form right angles.

Visual Literacy: Transverse Wave

Ask students to recall what they know about right angles. Explain that the term *transverse* means "made at right angles." Then have students read the first two paragraphs on this page. Explain that the top of a transverse wave is the *crest* and the bottom is the *trough*. Have students study the transverse wave in **Figure 3**. Explain that as the hand moves, it results in vibrations that make a wave along the rope.



Ask: In which direction does the disturbance move? *The disturbance moves up and down.*

Ask: What is the direction of the disturbance in a transverse wave? *perpendicular to the direction the wave travels* In which direction does the transverse wave in this diagram travel? *The wave travels from left to right.*

Differentiated Instruction

AL Make Waves Have students work together in pairs o teams. Give each pair or group a long piece of string a coiled spring toy. Ask them to create transverse waves using the string and longitudinal waves with the coil. T have them write short sentences to explain how they r each type of mechanical wave.

BL Create Dictionary Entries Have each student create dictionary entries for the terms *mechanical wave*, *electromagnetic wave*, *transverse wave*, and *longitudi wave*. They should write a definition for each term in th own words and include pronunciations from the dictior

Teacher Toolbox

Reading Strategy

Summarize Have students reread the section entitled **Two Main Types of Waves**. Ask them to write a short summary to define mechanical waves and electromagnetic wave Remind them that summaries should primarily include t main ideas of a topic and few supporting details.

Teacher Demo

Transverse Waves in a Towel Hold up a large piece of cloth such as a beach towel or tablecloth, by one end. Ask a s to hold the other end. Gently shake the cloth and have t class observe the waves that move through the cloth.

Ask: Are these mechanical waves or electromagnetic waves? *mechanical waves* **Ask:** How are they created? *Moving the towel causes particles to vibrate in the towel.* **Ask:** What kind of mechanical waves are they? *transverse waves* **Ask:** How does the disturbance move? *perpendicular to the wave's direction*

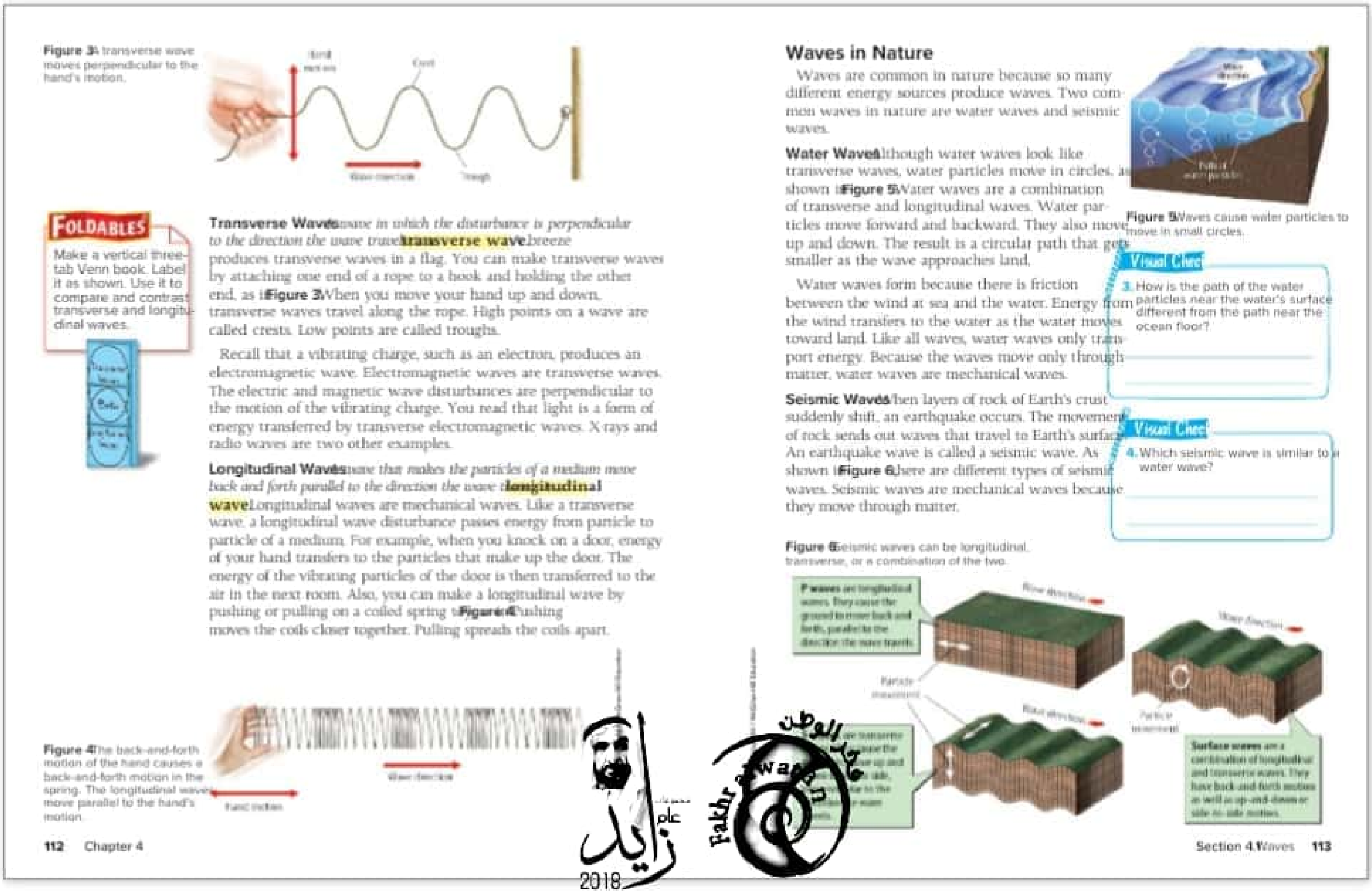


Figure 3 A transverse wave moves perpendicular to the hand's motion.

FOLDABLES

Make a vertical three-tab Venn book. Label it as shown. Use it to compare and contrast transverse and longitudinal waves.

Transverse Waves *wave in which the disturbance is perpendicular to the direction the wave travels* **transverse wave**. *breeze* produces transverse waves in a flag. You can make transverse waves by attaching one end of a rope to a hook and holding the other end, as in **Figure 3**. When you move your hand up and down, transverse waves travel along the rope. High points on a wave are called crests. Low points are called troughs.

Recall that a vibrating charge, such as an electron, produces an electromagnetic wave. Electromagnetic waves are transverse waves. The electric and magnetic wave disturbances are perpendicular to the motion of the vibrating charge. You read that light is a form of energy transferred by transverse electromagnetic waves. X-rays and radio waves are two other examples.

Longitudinal Waves *wave that makes the particles of a medium move back and forth parallel to the direction the wave travels* **longitudinal wave**. Longitudinal waves are mechanical waves. Like a transverse wave, a longitudinal wave disturbance passes energy from particle to particle of a medium. For example, when you knock on a door, energy of your hand transfers to the particles that make up the door. The energy of the vibrating particles of the door is then transferred to the air in the next room. Also, you can make a longitudinal wave by pushing or pulling on a coiled spring in **Figure 4**. Pushing moves the coils closer together. Pulling spreads the coils apart.

Figure 4 The back-and-forth motion of the hand causes a back-and-forth motion in the spring. The longitudinal waves move parallel to the hand's motion.

Waves in Nature

Waves are common in nature because so many different energy sources produce waves. Two common waves in nature are water waves and seismic waves.

Water Waves Although water waves look like transverse waves, water particles move in circles, as shown in **Figure 5**. Water waves are a combination of transverse and longitudinal waves. Water particles move forward and backward. They also move up and down. The result is a circular path that gets smaller as the wave approaches land.

Water waves form because there is friction between the wind at sea and the water. Energy from the wind transfers to the water as the water moves toward land. Like all waves, water waves only transport energy. Because the waves move only through matter, water waves are mechanical waves.

Figure 5 Waves cause water particles to move in small circles.

Visual Check

3. How is the path of the water particles near the water's surface different from the path near the ocean floor?

Seismic Waves When layers of rock of Earth's crust suddenly shift, an earthquake occurs. The movement of rock sends out waves that travel to Earth's surface. An earthquake wave is called a seismic wave. As shown in **Figure 6**, there are different types of seismic waves. Seismic waves are mechanical waves because they move through matter.

Visual Check

4. Which seismic wave is similar to a water wave?

Figure 6 Seismic waves can be longitudinal, transverse, or a combination of the two.

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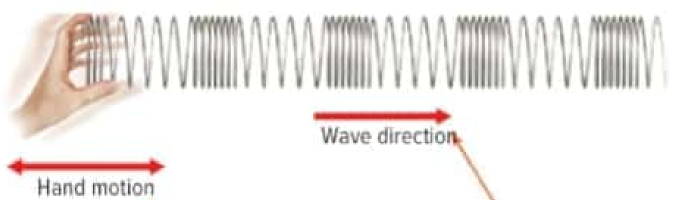
Visual Literacy: Longitudinal Wave

Have students read the next paragraph and discuss the difference between *perpendicular* and *parallel*. Then discuss the longitudinal wave in **Figure 4**. Explain that as the hand pulls back, it results in vibrations that create a wave along the coiled spring.



Ask: **In which direction does the disturbance move in this image?** *The disturbance moves from left to right.*

Ask: **In which direction does the longitudinal wave in this diagram travel?** *The wave also travels from left to right.*

Ask: **What is the direction of disturbance in a longitudinal wave?**
parallel to the direction the wave travels

Waves in Nature

Remind students that water waves are a combination of transverse and longitudinal waves. Explain that another type of wave also moves back and forth, up and down, and side to side. However, it moves through land instead of water. Have students read this page and study the diagram in **Figure 5**. Then ask these questions to informally assess their understanding.

Guiding Questions

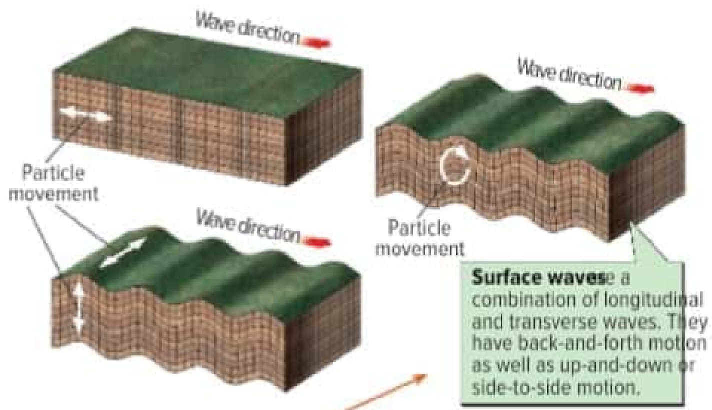
AL What causes water waves?	*Wind pushes against the water and forms waves.*
OL How is the path of the water particles near the water's surface different from the path near the ocean floor?	*The water particles near the water's surface move in larger circles than the particles near the ocean floor.*
BL Why do water waves move in circles?	*Water waves are a combination of transverse waves and longitudinal waves, so they move up and down and back and forth.*

Visual Literacy: Seismic Waves

Have students study **Figure 6** and compare the different types of seismic waves. Explain that "P" stands for "primary." Primary waves are the fastest and can travel through solids, liquids, and gases. The "S" stands for "secondary." Secondary waves are slower than

P waves and can travel only through solids. Surface waves are the slowest and can travel only along Earth's surface.

Ask: Why are seismic waves classified as mechanical waves? *Seismic waves are mechanical waves because they move through matter.*



Ask: Which seismic wave is similar to a water wave? *surface wave*

Ask: Which type of wave moves in the same direction as the particles in the wave move? *primary wave*

Differentiated Instruction

AL Draw a Diagram Have students draw a diagram that illustrates how a wave transfers energy but not matter. Students can show waves created by a pebble droppe pool of water, use the 'human wave' example from the teacher demonstration, or a lightbulb example. Their diagrams should include a short caption that explains h waves transfer energy.

BL Write a Short Story Have students write a short story that describes what happens in a crowded lake when a large wave passes or on land after a seismic wave pas below ground. Students should provide details that de the impact of a wave in nature.

Teacher Toolbox

Reading Strategy

Compare/Contrast Have students write a short paragraph to compare and contrast water waves and seismic wav including the kinds of materials each type of wave mov through, how they cause particles in the medium to mo and at least one effect of each type of wave.

Careers in Science

Seismology The study of seismic waves is known as seismology. It includes the use of a machine called a seismograph, which registers seismic waves and reco the motion of the ground during an earthquake. The information that scientists (called seismologists) gathe helps them learn more about earthquakes and their ef

Real-World Science

Seismic Reflection and Refraction Seismic waves move differently through different types of rock. When they t through rocks of different densities, the speeds and directions of the waves change. By studying these cha scientists can learn more about how seismic waves tra

Properties of Waves

How could you describe water waves at a beach? You might describe properties such as the height or the speed of the wave. When scientists describe waves, they describe the properties of wavelength and frequency.

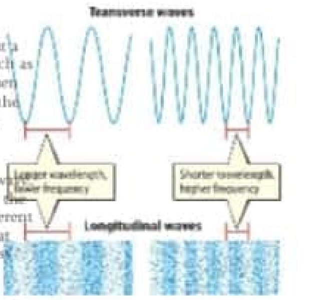


Figure 7 You can describe the wavelength and the frequency of both transverse and longitudinal waves.

Wavelength

The distance between a point on one wave, such as the crest, and the same point on the next wave is called the wavelength. Different types of waves can have wavelengths that range from thousands of kilometers to less than the size of an atom!

Frequency

The number of wavelengths that pass a point each second is a wave's **frequency**. Frequency is measured in hertz (Hz). One hertz equals one wave per second. As shown in **Figure 7**, the longer the wavelength, the lower the frequency. As the distance between the crests gets shorter, the number of waves passing a point each second increases.

Reading Check

5. What is frequency?

Describe

List the main ideas from this section in the box below.

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Wave Speed

A wave's speed depends on the medium, or type of material, through which it travels. Electromagnetic waves always travel through empty space at the same speed, 3 × 10⁸ m/s. That's 300 million meters each second! They travel slower through a medium, or matter, because they must interact with particles. Mechanical waves also travel slower through matter because the waves transfer energy from one particle to another. For example, sound waves travel about one-millionth the speed of light waves. The speed of water waves depends on the strength of the wind that produces them. **Table 2** compares the speeds of different types of waves.

Table 2 Wave Speeds

Type of Wave	Typical wave speed (m/s)
Ocean wave	25
Sound wave in air	340
Transverse seismic wave (S wave)	1,000 to 8,000
Longitudinal seismic wave (P wave)	1,000 to 14,000
Electromagnetic wave through empty space	300,000,000

Table 2 The speed of a wave depends on the type of wave and the medium through which the wave travels.

Amplitude and Energy

Different waves carry different amounts of energy. Some earthquakes, for example, are catastrophic because they carry so much energy. A shift in Earth's crust can cause particles in the crust to vibrate back and forth very far from their rest positions, producing seismic waves. In January 2010, seismic waves in Haiti transferred enough energy to destroy entire cities.

A wave's **amplitude** is *the maximum distance a wave varies from its rest position.* For mechanical waves, amplitude is the maximum distance the particles of the medium move from their rest positions as a wave passes. The more energy a mechanical wave has, the larger its amplitude. The amplitude of a transverse mechanical wave is shown in **Figure 8**.

Key Concept Check

6. How can you describe waves?

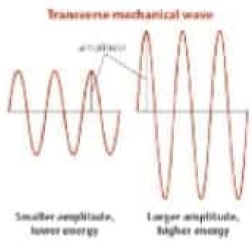

Figure 8 As more energy is used to produce a mechanical wave, particles of a medium vibrate farther from their rest positions.

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Properties of Waves

Explain that waves have different properties that can be used to describe how they move and behave. Then have students read the first paragraph on this page.

Wavelength / Frequency

Refer students to **Figure 7** and have them compare the lengths of the red lines. Wavelength is the distance from a specific point on one wave to the same relative point on the next wave. Frequency is the number of wavelengths that pass a point in one second. **Ask:** **Which wave do you think takes longer to pass a given point?** *The wave with the longer wavelength.* **Why?** *There is more of it to pass the point.*

Guiding Questions

AL Which unit is used to measure wave frequency?	*hertz*
OL What is frequency?	*The number of wavelengths that pass a point each second.*
BL If a wave's frequency is 0.5 Hz, how long does it take to pass a point?	*two seconds*

Wave Speed

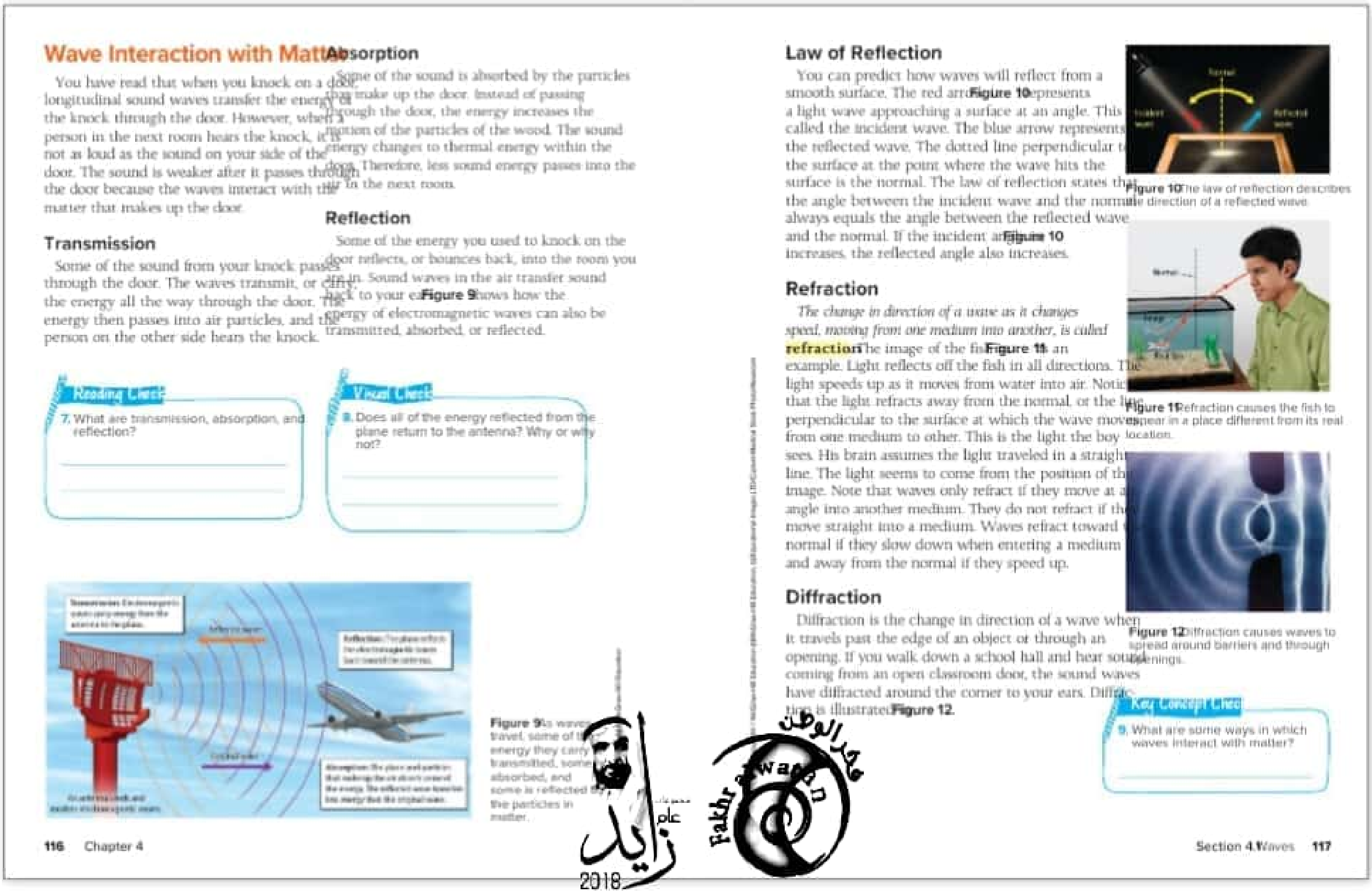
Remind students that wavelength and frequency are two properties of waves. Have them discuss their experiences in the **MiniLab** and the properties of the waves they created. Then have them read the first paragraph and study **Table 2.**

Amplitude and Energy

Explain that amplitude is another wave property. Refer students to **Figure 3**. Explain that the person moving the rope would need to use more energy to make waves that had higher crests and lower troughs. Then refer students to **Figure 8** and note that the wave with the higher crests and lower troughs has higher energy. Amplitude is a measure of the energy a wave carries. All waves have measurable amplitudes.

Guiding Questions

AL What is amplitude?	*Amplitude is the maximum distance a wave varies from its rest position.*
OL How can you describe waves?	*You can describe a wave by its wavelength, frequency, speed, amplitude, and energy*
BL How can you decrease the amplitude of a sound wave?	*You can reduce the amount of energy the wave carries.*



Wave Interaction with Matter

You have read that when you knock on a door, longitudinal sound waves transfer the energy of the knock through the door. However, when a person in the next room hears the knock, it is not as loud as the sound on your side of the door. The sound is weaker after it passes through the door because the waves interact with the matter that makes up the door.

Transmission

Some of the sound from your knock passes through the door. The waves transmit, or carry, the energy all the way through the door. The energy then passes into air particles, and the person on the other side hears the knock.

Absorption

Some of the sound is absorbed by the particles that make up the door. Instead of passing through the door, the energy increases the motion of the particles of the wood. The sound energy changes to thermal energy within the door. Therefore, less sound energy passes into the air in the next room.

Reflection

Some of the energy you used to knock on the door reflects, or bounces back, into the room you are in. Sound waves in the air transfer sound back to your ear. Figure 9 shows how the energy of electromagnetic waves can also be transmitted, absorbed, or reflected.

Reading Check
7. What are transmission, absorption, and reflection?

Visual Check
8. Does all of the energy reflected from the plane return to the antenna? Why or why not?

Figure 9 As waves travel, some of the energy they carry is transmitted, some is absorbed, and some is reflected by the particles in matter.

116 Chapter 4

Law of Reflection

You can predict how waves will reflect from a smooth surface. The red arrow in Figure 10 represents a light wave approaching a surface at an angle. This is called the incident wave. The blue arrow represents the reflected wave. The dotted line perpendicular to the surface at the point where the wave hits the surface is the normal. The law of reflection states that the angle between the incident wave and the normal always equals the angle between the reflected wave and the normal. If the incident angle in Figure 10 increases, the reflected angle also increases.

Figure 10 The law of reflection describes the direction of a reflected wave.

Refraction

The change in direction of a wave as it changes speed, moving from one medium into another, is called **refraction**. The image of the fish in Figure 11 is an example. Light reflects off the fish in all directions. The light speeds up as it moves from water into air. Notice that the light refracts away from the normal, or the line perpendicular to the surface at which the wave moves from one medium to other. This is the light the boy sees. His brain assumes the light traveled in a straight line. The light seems to come from the position of the image. Note that waves only refract if they move at an angle into another medium. They do not refract if they move straight into a medium. Waves refract toward the normal if they slow down when entering a medium and away from the normal if they speed up.

Figure 11 Refraction causes the fish to appear in a place different from its real location.

Diffraction

Diffraction is the change in direction of a wave when it travels past the edge of an object or through an opening. If you walk down a school hall and hear sound waves coming from an open classroom door, the sound waves have diffracted around the corner to your ears. Diffraction is illustrated in Figure 12.

Figure 12 Diffraction causes waves to spread around barriers and through openings.

Key Concept Check
9. What are some ways in which waves interact with matter?

Section 4.1 Waves 117

Wave Interaction with Matter

Bring to class a clear plastic container and an object that makes noise, such as an alarm clock or a music box. Explain that these objects will help students understand what can happen when waves interact with matter.

Transmission / Absorption

Turn on the clock's alarm or music box so that everyone can hear it. Then place it under the plastic container. Students should be able to hear the noise but it should be quieter. Explain that this is an example of transmission and absorption. The sound is quieter because the box absorbs some of the sound waves. However, you can still hear the sound because the box transmits some of the sound waves. Then have students read the next two paragraphs on this page. **Ask:** **How does the plastic container transmit sound waves?** *The energy of the sound waves is carried by the particles in the container and transmitted to the air.*

Reflection

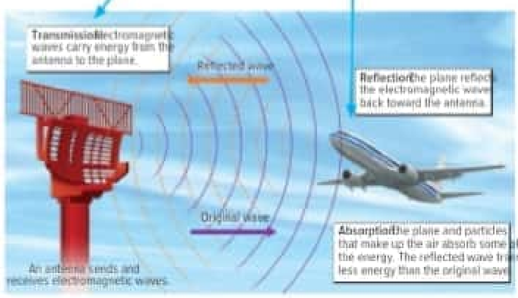
Take the clock or music box out of the room but next to an open door so that students cannot see the it but can hear it. **Ask:** **How can you still hear the sound?** *Sound waves bounce off walls and travel to my ears.* Have students read the last paragraph on this page. **Ask:** **Wood transmits sound better than foam. Why do you think this is?** *Vibrating particles transmit sound. The closer together the particles are, the better the sound is transmitted. The particles in wood are closer together than the particles in foam.*

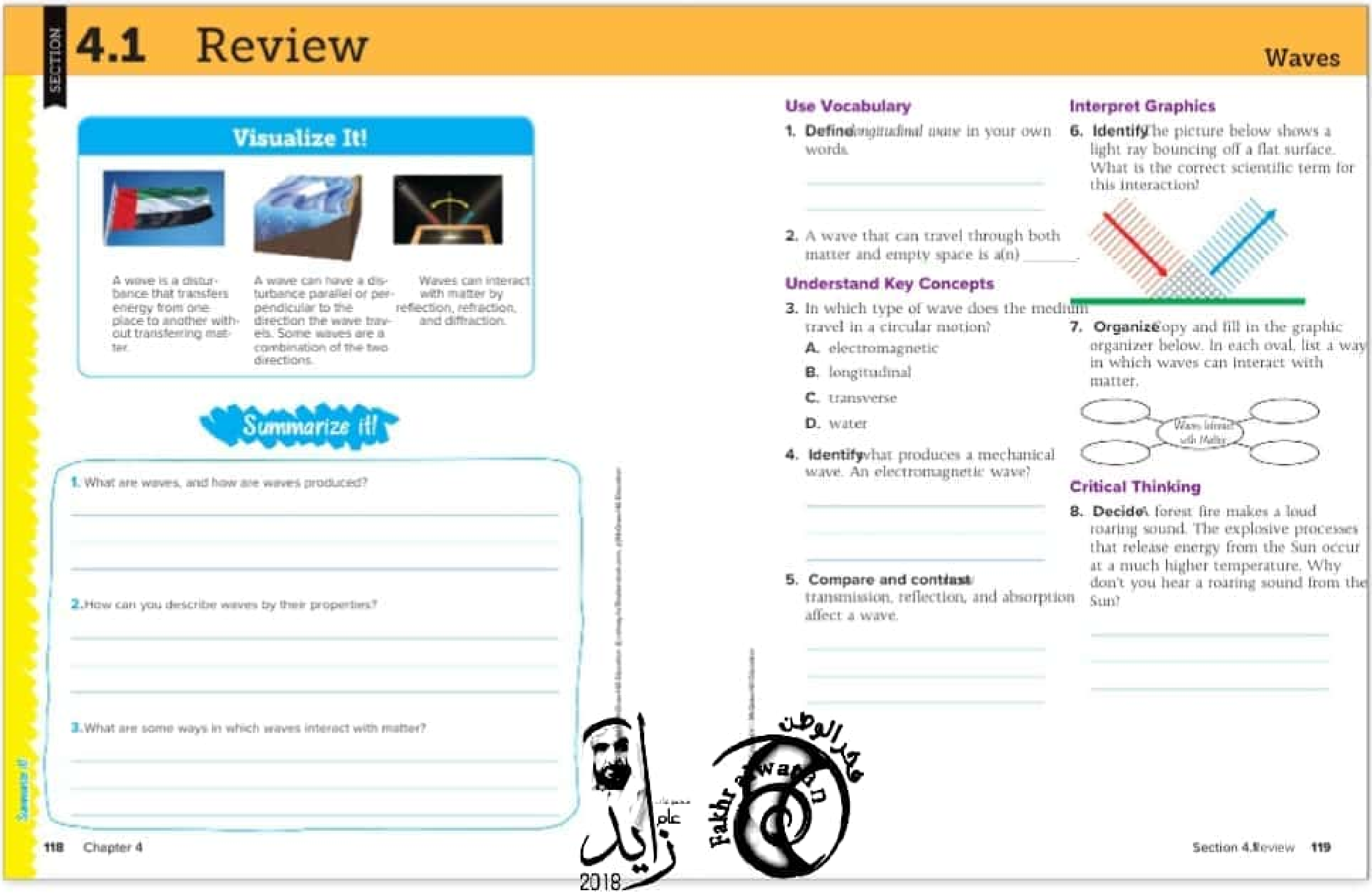
Visual Literacy: Transmission, Absorption, and Reflection

Have students study the illustration in Figure 9. Ask these questions to informally assess students' understanding of the different ways waves can interact with matter.

Ask: **What are transmission, absorption, and reflection?** *Transmission is the transfer of wave energy through a medium. Absorption is the transfer of wave energy to the medium through which the wave travels. Reflection is the bouncing of a wave off a surface.*

Ask: **Does all of the energy reflected from the plane return to the antenna? Why or why not?** *No, the plane and particles in the air absorb some of the energy.*





SECTION 4.1 Review

Waves

Visualize It!

A wave is a disturbance that transfers energy from one place to another without transferring matter.

A wave can have a disturbance parallel or perpendicular to the direction the wave travels. Some waves are a combination of the two directions.

Waves can interact with matter by reflection, refraction, and diffraction.

Summarize it!

1. What are waves, and how are waves produced?

2. How can you describe waves by their properties?

3. What are some ways in which waves interact with matter?

118 Chapter 4

Use Vocabulary

1. **Define** *longitudinal wave* in your own words.

2. A wave that can travel through both matter and empty space is a(n) ______.

Understand Key Concepts

3. In which type of wave does the medium travel in a circular motion?
   - A. electromagnetic
   - B. longitudinal
   - C. transverse
   - D. water

4. **Identify** what produces a mechanical wave. An electromagnetic wave?

5. **Compare and contrast** transmission, reflection, and absorption affect a wave.

Interpret Graphics

6. **Identify** The picture below shows a light ray bouncing off a flat surface. What is the correct scientific term for this interaction?

7. **Organize** Copy and fill in the graphic organizer below. In each oval, list a way in which waves can interact with matter.

Waves Interact with Matter

Critical Thinking

8. **Decide** A forest fire makes a loud roaring sound. The explosive processes that release energy from the Sun occur at a much higher temperature. Why don't you hear a roaring sound from the Sun?

Section 4.1 Review 119

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Use Vocabulary

1. Sample answer: In a longitudinal wave, each particle in the medium vibrates back and forth, parallel to the direction in which the wave travels.

2. electromagnetic wave

Understand Key Concepts

3. D. water

4. A mechanical wave is produced when a source of energy causes particles of matter to vibrate. An electromagnetic wave is produced when a source of energy causes charged particles to vibrate.

5. Transmission transfers wave energy through a material. Absorption transfers wave energy to the medium through which the wave travels. Reflection is the bouncing of a wave off a surface.

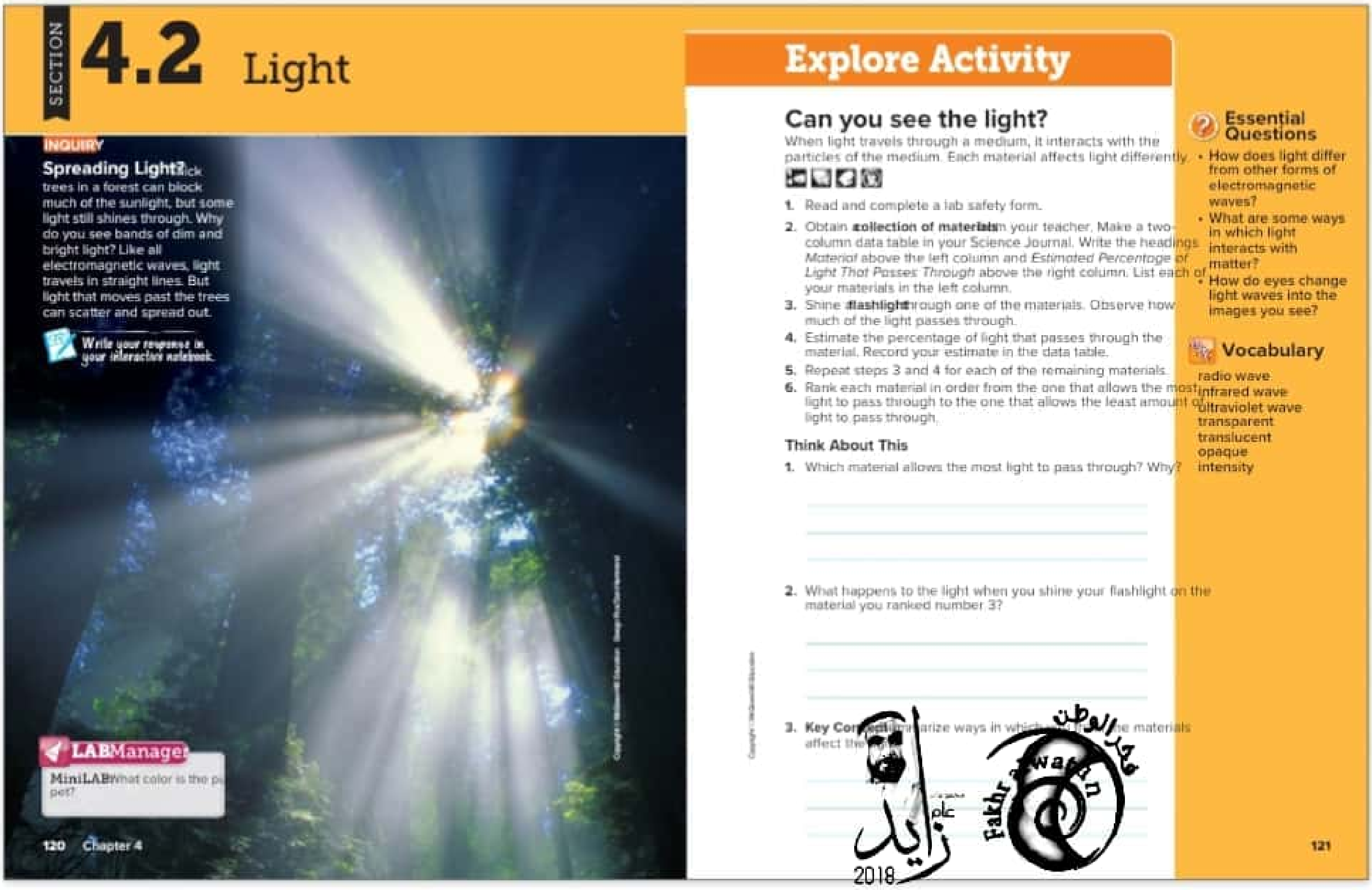
Interpret Graphics

6. reflection

7. List any four of these five answers: absorption, reflection, refraction, diffraction, transmission.

Critical Thinking

8. We cannot hear the explosions on the Sun because sound is a mechanical wave and cannot travel through space.


SECTION 4.2 Light

INQUIRY

Spreading Light? Thick trees in a forest can block much of the sunlight, but some light still shines through. Why do you see bands of dim and bright light? Like all electromagnetic waves, light travels in straight lines. But light that moves past the trees can scatter and spread out.

Write your response in your interactive notebook.

LABManager

MiniLAB What color is the p... pet?

Explore Activity

Can you see the light?

When light travels through a medium, it interacts with the particles of the medium. Each material affects light differently.

1. Read and complete a lab safety form.
2. Obtain a collection of materials from your teacher. Make a two-column data table in your Science Journal. Write the headings *Material* above the left column and *Estimated Percentage of Light That Passes Through* above the right column. List each of your materials in the left column.
3. Shine a flashlight through one of the materials. Observe how much of the light passes through.
4. Estimate the percentage of light that passes through the material. Record your estimate in the data table.
5. Repeat steps 3 and 4 for each of the remaining materials.
6. Rank each material in order from the one that allows the most light to pass through to the one that allows the least amount of light to pass through.

Think About This

1. Which material allows the most light to pass through? Why?
2. What happens to the light when you shine your flashlight on the material you ranked number 3?
3. Key Concept Summarize ways in which ... materials affect the ...

Essential Questions

- How does light differ from other forms of electromagnetic waves?
- What are some ways in which light interacts with matter?
- How do eyes change light waves into the images you see?

Vocabulary

radio wave
infrared wave
ultraviolet wave
transparent
translucent
opaque
intensity

INQUIRY

About the Photo **Spreading Light?** Instruct students to look at the photograph of light shining through the forest. Have them consider what they know about how waves travel and the energy they transmit in order to make predictions about light waves.

Guiding Questions

AL Where does the light appear to be the brightest?	*Near the top of the picture, behind the trees, where you see what might be the Sun.*
OL Where does the light appear the dimmest?	*Near the bottom of the picture and to the left and right, which are farthest from the beam of light.*
BL Why do you think certain areas of the forest are illuminated by the light waves better than other areas?	*The forest is brightest where there are fewer objects blocking the light and where you can see its source. The forest is darkest where the trees are thickest and in those areas farthest from the light beam.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Develop Prior Knowledge

1. Write this lesson's vocabulary terms on the board.
2. Ask students to read them and think about which terms they have heard before. Students are likely to be familiar with the words *transparent* and *intensity*, among others.
3. Working together as a class, have student create definitions for any terms they already know. Write their definitions on chart paper or the board.
4. After completing the lesson, return to the definitions and revise them as needed or include additional information that students have learned.

Explore Activity

Can you see the light?

Purpose
To observe how light interacts with different materials.

Materials
a collection of five materials that can cover the end of a flashlight such as white paper, gauze, plastic wrap, a textbook, or paper towel

Before You Begin
Discuss percentage and estimation. Tell the students that their estimations can be whole numbers.

Guide the Investigation
Make the classroom as dark as possible for best results with this lab. Students should shine the flashlight 15 cm to 20 cm from the same white surface or white piece of paper for each trial.

Material	Estimated amount of light (%)	F
White paper	20%	4
Gauze	80%	2
Textbook	0%	5
Plastic	100%	1
Paper towel	40%	3

Think About This
1. Answers will vary. The plastic wrap allowed the most light to pass through because it was clear.
2. Some of the light was blocked, but some of the light passed through.
3. **Key Concept** Answers will vary. The light waves are blocked by particles that make up each material.

Teacher Notes

Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

What are light waves?

You have read that there are two main types of waves–mechanical and electromagnetic. Mechanical waves move only through matter, but electromagnetic waves can move through matter and through empty space. Now you will read about different types of electromagnetic waves. The most familiar type of electromagnetic wave is light.

Recall that vibrating charged particles produce electromagnetic waves with many different wavelengths. Only a narrow range of these wavelengths are detected by most people's eyes. This small range of electromagnetic waves is what is known as light. Light waves and other forms of electromagnetic waves differ in wavelength and frequency.

An object that produces light is a luminous object. The Sun is Earth's major source of visible light. Almost half the Sun's energy that reaches Earth is visible light. Other luminous objects include lightbulbs and objects that produce light as they burn, such as a campfire.

Academic Vocabulary

range
(noun) set of values from least to greatest

Key Concept Check

1. How does light differ from other forms of electromagnetic waves?

The Electromagnetic Spectrum

Light is just a one type of electromagnetic wave. There is a wide range of electromagnetic waves that make up the electromagnetic spectrum, shown in **Figure 13**. Besides light, you encounter several other types of electromagnetic waves every day, and they probably play an important role in your life.

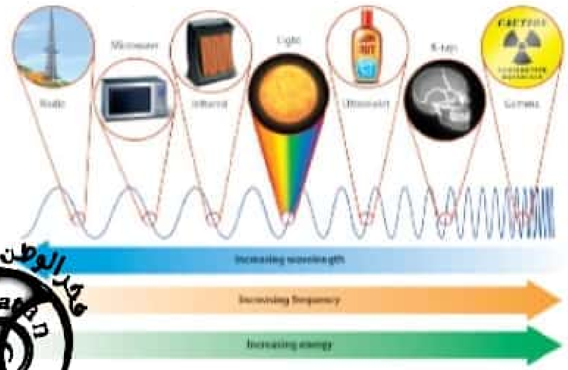
Types of Electromagnetic Waves

The electromagnetic spectrum consists of seven main types of waves. These waves range from low-energy, long-wavelength radio waves to very high-energy, short-wavelength gamma rays. Notice the relationship between wavelength, frequency, and energy indicated by the arrows in **Figure 13**. As the wavelength of electromagnetic waves decreases, the wave frequency increases. Low-frequency electromagnetic waves carry low amounts of energy, and high-frequency waves carry high amounts of energy.

Radio Waves A *low-frequency, low-energy electromagnetic wave that has a wavelength longer than about 30 cm* is a **radio wave**. Radio waves have the least amount of energy of any electromagnetic wave. On Earth, radio and television transmitters produce radio waves that carry radio and television signals.

Microwaves You might use microwaves to cook your food. Microwaves also carry cell phone signals. Wavelengths of microwaves range from about 1 mm to 30 cm. Microwaves easily pass through smoke, light rain, and clouds, which makes them useful for transmitting information by satellites. Weather radar systems reflect microwaves off rain or storm clouds to detect and calculate the storm's distance and motion. Then, these calculations are used to make weather maps like the one shown on the first page of this chapter.

Figure 13 Electromagnetic waves have different wavelengths, frequencies, and energy.



What are light waves?

Remind students that visible light is electromagnetic waves. Discuss sources of light, such as the Sun, lamps, flashlights, candles, and fire. Then have students read the paragraphs.

Ask: **How does light differ from other forms of electromagnetic waves?** *Light is the only type of electromagnetic wave that you can see.* It differs from other forms of electromagnetic waves in its wavelengths, its frequencies, and the amount of energy it carries.

Academic Vocabulary

range

Have students review the definition of *range*. Ask them to name examples of numerical ranges, such as the range of measurements of students' heights or their ages.

The Electromagnetic Spectrum

Review the definition of an electromagnetic wave—a wave that can travel through matter and through empty space. Remind students that this wave type forms when charged particles vibrate. Then have students read the first paragraph and preview the different types of waves shown in **Figure 13.**

Types of Electromagnetic Waves

Discuss with students their prior knowledge of radio waves and microwaves. Student may note that both are invisible and that we use them for different things. Remind students that wavelength is the distance from one point on a wave to the nearest identical point, and frequency measures the number of identical wavelengths that pass a point each second. Have students read the remaining paragraphs on this page.

Guiding Questions

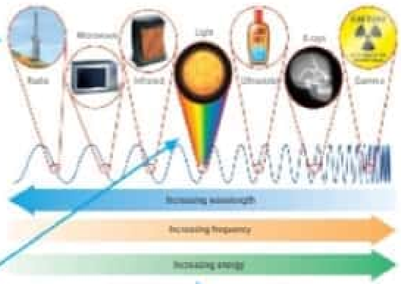
AL What is the wavelength of a radio wave?	*A radio wave's wavelength is longer than 30 cm.*
AL What is the range of wavelengths of microwaves?	*The wavelength of a microwave is between 1 mm and 30 cm.*
OL How do we use radio waves? How do we use microwaves?	*We use radio waves to carry radio and television signals. We use microwaves to cook food and carry cell phone signals.*

Visual Literacy: The Electromagnetic Spectrum

Have students examine **Figure 13** to compare the different kinds of waves along the electromagnetic spectrum. Ask these questions to assess understanding.

Ask: **Why do radio waves have the lowest frequency of all the waves on the electromagnetic spectrum?** *Radio waves are low-frequency waves because they have the longest wavelengths.*

Ask: **Which has a longer wavelength, light or X-rays? How do you know?** *Light has longer wavelengths than X-rays. Light is to the left of X-rays on the electromagnetic spectrum.*



Ask: **How do wavelength, frequency, and energy change as you move from left to right along the electromagnetic spectrum?** *Wavelength decreases but frequency and energy increase.*

Light / Infrared Waves

Review the two types of electromagnetic waves students have studied so far in this lesson—radio waves and microwaves. Refer them to **Figure 13** and instruct them to note where visible light and infrared waves are on the spectrum. Discuss the image used to represent these waves and discuss how they compare to radio waves and microwaves in terms of wavelength, energy, and frequency. Have students read the paragraphs on light and infrared waves and study the photo in **Figure 14**. Review the definition of infrared and then ask the following questions to assess students' comprehension.

Guiding Questions

AL Do infrared waves have wavelengths that are longer or shorter than visible light waves?	*Infrared waves have wavelengths that are longer than those of visible light.*
AL Does an infrared wave have a frequency that is higher or lower than a microwave?	*Infrared waves have a higher frequency than microwaves.*
OL How do infrared waves and microwaves differ?	*Infrared waves have shorter wavelengths, higher frequency, and more energy than microwaves.*

Differentiated Instruction

AL Define Unfamiliar Terms Have students reread the sections entitled **What are light waves?** and **The Electromagnetic Spectrum.** Ask them to write a list of any unfamiliar words that are not vocabulary terms, such as *detect* or *luminous*. Have students use a dictionary to w a definition of each new term in their own words. Then them to reread both sections, referring to their definitio needed.

BL Graph Electromagnetic Waves Have students conduct research to learn the range of wavelengths for visible li waves. They should use the information they learn to m a graph that compares the wavelengths of visible light, waves, and microwaves.

Teacher Toolbox

Reading Strategy

Make Word Connections Have students work together in pairs to review the first two pages in this lesson. Studen should take turns naming important words about light waves, such as *light, electromagnetic,* and *visible*. The student's partner should then name a related word fro lesson. For example, if the first student says radio wav related term might be *low-energy*. Have partners take t naming words and related terms.

Fun Fact

Comparing Wavelengths Radio waves have the longest wavelengths of all the waves on the electromagnetic spectrum. They can be as long as a football field, abou 100 m. Microwaves, the next longest, can range in size the length of a bee to size of the head of a pin. The sm electromagnetic waves, X-rays and gamma rays, have wavelengths that are no bigger than an atom or its nuc

Real-World Science

What's the frequency? Every radio station broadcasts its signal in a specific frequency. The number of the statio such as 102.7 or 550, is the frequency of its broadcast waves in megahertz. You need to turn your radio to the rig frequency to listen to the station.

Cultural Diversity

An Early Study of Light An Arab physicist named Alhazen was one of the first scientists to study light. In the late 9 and early 1000s, he studied reflection, refraction, and c He was also the first scientist to accurately describe the parts of the eye and explain the process of vision.

Figure 14 Infrared waves travel outward in all directions from the campfire.

Light When you turn on a lamp or stand in sunshine, you probably don't think about waves entering your eyes. However, as you have read, light is a type of electromagnetic wave that the eyes detect. Light includes a range of wavelengths. You will read later in this lesson how this range of wavelengths relates to various properties of light.

Infrared Waves *An electromagnetic wave with a wavelength shorter than a microwave but longer than light is an* **infrared wave.** When you sit near a heater or a campfire, as **Figure 14** infrared waves transfer energy to your skin, and you feel warm. The Sun is Earth's major source of infrared waves. However, vibrating molecules in any type of matter, including your body, emit infrared waves.

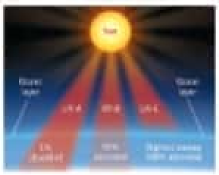
Word Origin

infrared
from Latin *infra*, means "below"; and *ruber*, means "red"

ultraviolet
from Latin *ultra*, means "beyond"; and *viola*, means "violet"

Ultraviolet Waves *An electromagnetic wave with a slightly shorter wavelength and higher frequency than light is an* **ultraviolet wave.** Electromagnetic waves with shorter wavelengths carry more energy than those with longer wavelengths and, therefore, can be harmful to living things. You might have heard that ultraviolet waves, or UV rays, from the Sun can be dangerous. These waves carry enough energy to cause particles of matter to combine or break apart and form other types of matter. Exposure to high levels of these waves can damage your skin.

Figure 15 The ozone layer protects Earth from the most dangerous ultraviolet waves from the Sun.



Ultraviolet waves from the Sun are sometimes labeled UV-A, UV-B, or UV-C based on their wavelengths. UV-A have the longest wavelengths and the least energy. UV-C are the most dangerous because they have the shortest wavelengths and carry the most energy. As shown in **Figure 15**, the ozone layer in Earth's atmosphere blocks the Sun's most harmful UV rays from reaching Earth.

Reading Check
2. How do infrared waves and microwaves differ?

Reading Check
3. Why can ultraviolet waves be dangerous?

X-rays High-energy electromagnetic waves that have slightly shorter wavelengths and higher frequencies than ultraviolet waves are X-rays. These waves can be very powerful. They have enough energy to pass through skin and muscle, but denser bone can stop them. This makes them useful for taking pictures of the inside of the body. Airport scanners, as in **Figure 16**, sometimes use X-rays to take pictures of the contents of luggage.

Figure 16 X-rays are useful for security scans because they have enough energy to pass through soft parts of luggage.

Visual Check
4. How do the views of hard parts and soft parts of luggage differ in this X-ray image?

Gamma Rays Electromagnetic waves produced by vibrations within the nucleus of an atom are called gamma rays. They have shorter wavelengths and higher frequencies than any other form of electromagnetic wave. Gamma rays carry so much energy that they can penetrate about 10 cm of lead, one of the densest elements. On Earth, gamma rays are produced by radioactive elements and nuclear reactions.

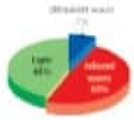
Reading Check
5. Why do you think gamma rays cannot be used for communication in the same way radio waves are used?

Electromagnetic Waves from the Sun

The Sun produces an enormous amount of energy that is carried outward in all directions as electromagnetic waves. Because Earth is so far from the Sun, Earth receives less than one-billionth of the Sun's energy. However, if all the Sun's energy that reaches Earth in a 20-minute period could be transformed to useful energy, it could power the entire Earth for a year!

...wn in **Figure 17**, about 44 percent of the Sun's ... reaches Earth is carried by light waves, and ...ercent is carried by infrared waves. About ... is carried by ultraviolet waves. Radio waves, ...wa...es, X-rays, and gamma rays carry less than ...ercent of the Sun's energy.

Figure 17 Infrared waves, light, and ultraviolet waves carry almost all of the Sun's energy.



Word Origin

infrared, ultraviolet

Have students read the Latin origin of *infrared* and *ultraviolet*. **Ask: How does the origin of these words relate to their positions on the electromagnetic spectrum?** *The Latin origins of infrared mean below red, and an infrared wave has an energy and a frequency that is just below those of a red wave. The Latin origins of ultraviolet mean beyond violet and an ultraviolet wave has energy and a frequency beyond those of a violet wave.*

Ultraviolet Waves

Refer to **Figure 13**. Again, note where ultraviolet waves are on the spectrum and how they compare with other electromagnetic waves. Have students read the remaining paragraphs on this page and study the image in **Figure 15**. Then ask the following questions to assess students' comprehension.

Guiding Questions

AL Is the wavelength of ultraviolet light shorter or longer than that of visible light?	*The wavelength of ultraviolet light is shorter than that of visible light.*
OL Why can ultraviolet waves be dangerous?	*Ultraviolet waves can be dangerous because they carry enough energy to cause particles of matter to combine or break apart and form other types of matter.*

X-rays / Gamma Rays

Continue the activity in which students note where the wave type they are about to study is on the electromagnetic spectrum and how it compares to the types they have already learned. Have students read the first two paragraphs on this page and study **Figure 16** to learn about the last two kinds of waves along the electromagnetic spectrum. Then ask these questions.

Guiding Questions

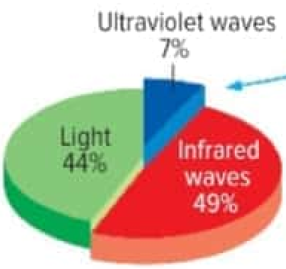
AL What kind of wave has slightly shorter wavelengths than ultraviolet waves?	*X-rays*
OL Why do you think gamma rays can't be used for communication in the same way radio waves are used?	*They have so much energy that they would be dangerous.*
OL How do hard parts and soft parts of luggage appear in this X-ray image?	*The soft parts are nearly transparent. The hard parts appear as solid shapes.*
BL Radio waves bounce off walls, but gamma rays can penetrate through them. Why do you think that is the case?	*Gamma rays have more energy than radio waves.*

Electromagnetic Waves from the Sun

Have students read the last two paragraphs on the page. Explain that the Sun is the major source of all waves along the electromagnetic spectrum. Nevertheless, it is not the only natural source of these kinds of waves. Stars and other objects in space also are sources of electromagnetic waves. In addition, people, animals, and objects emit infrared waves.

Visual Literacy: The Sun's Energy

Refer students to **Figure 13.** Note that the three types of waves emitted by the Sun are side by side on the electromagnetic spectrum. Note the images representing each type of light and discuss how people sense warmth and light from the Sun and how sunscreens reflect the absorption of UV rays. Then refer students to **Figure 17.** Have students compare the different percentages of these varying electromagnetic waves produced by the Sun.



Ask: Which type of wave can cause a sunburn? *ultraviolet waves* How much of the Sun's energy is emitted as ultraviolet rays? *seven percent*

Ask: How much of the Sun's energy reaches Earth as infrared waves? *49 percent* How is that type of wave represented in Figure 13? *as a space heater*

Differentiated Instruction

Have students work together in pairs to research the wa the electromagnetic spectrum. They should learn more a the different waves and the ways that we use them. Afte completing their research, each pair should use what the learn to complete one of the following activities.

AL **Write a TV Script** Have pairs work together to write a short script for a science special on electromagnetic w They should explain some of the ways we use microwa gamma rays, radio waves, and so on.

BL **Design an Invention** Have pairs work together to design an invention that uses two or three different kir electromagnetic waves. For example, they might desig microwave oven that also broadcasts television progra They should create an illustration of their invention alo with a brief explanation of what it is and how it uses electromagnetic waves.

Teacher Toolbo

Reading Strategy

Compare/Contrast Have students create a Venn diagram that compares infrared waves to ultraviolet waves. Stu should include two ways in which they are the same (s as the source of the waves and their ability to travel th empty space) and one or two ways in which they are different (such as the fact that the human body emits infrared waves and UV rays can be dangerous).

Cultural Diversity

The Discovery of Gamma Rays French scientist named Paul Villard is credited with discovering gamma rays a 1900. He recognized that they were different from X-ra because they had more energy and could penetrate materials more deeply.

Integrate Career

Fighting Fires with Infrared Waves Firefighters often use infrared images produced by thermal imaging cameras These images can help them distinguish between the thermal energy emitted by people and the thermal ene from flames. That can help them find victims or injured fighters through smoke and haze or predict where the intense areas of a fire are located.

Speed, Wavelength, and Frequency

How could you describe the light from stars or the lights in a city at night? You might use words like *bright* or *dim*, or you might describe the color of the lights. You also could say how easily the light moves through a material. People use properties to describe light and to distinguish one color of light from another.

Like all types of electromagnetic waves, light travels at a speed of 3×10^8 m/s in empty space. When light enters a medium, or matter, it slows down. This is because of the interaction between the waves and the particles that make up the matter.

The wavelength and the frequency of a light wave determine the color of the light. The average human eye can distinguish among millions of wavelengths, or colors. Reds have the longest wavelengths and the lowest frequencies of light. Colors at the violet end of the visible light spectrum have the shortest wavelengths and the highest frequencies.

Light and Matter Interact

In Lesson 1, you read that matter can transmit, absorb, or reflect waves. How do these interactions affect light that travels from a source to your eyes?

Transmission

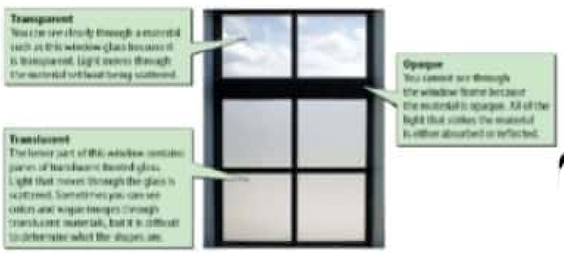
Air and clear glass, as shown in **Figure 18**, transmit light with little or no distortion. *A material that allows almost all of the light striking it to pass through, and through which objects can be seen clearly* is **transparent**.

Materials such as waxed paper or frosted glass also transmit light, but you cannot see through them clearly. *A material that allows most of the light that strikes it to pass through, but through which objects appear blurry* is **translucent**.

Absorption

Some materials absorb most of the light that strikes them. They transmit no light. Therefore, you cannot see objects through them. *A material through which light does not* pass is **opaque**.

Figure 18 Materials transmit, absorb, and reflect different amounts of light. This determines whether the material is transparent, translucent, or opaque.



Reflection

Why can you see your reflection clearly in a mirror, but not in the wall of your room? Recall that waves reflect off surfaces according to the law of reflection. Parallel rays that reflect from a smooth surface remain parallel and form a clear image. Light that reflects from a bumpy surface scatters in many directions. A wall seems smooth, but up close it is too bumpy to form a clear image.

Different types of matter interact with light in different ways. For example, the window in **Figure 18** both transmits and reflects light. Some of the light that strikes an opaque object, such as a book, is absorbed and reflected at the same time. Reflected light allows an object to be seen.

Color

The colors of an object depends on the wavelengths of light that enters the eye. A luminous object, such as a campfire, is the color of light that it emits. If an object is not luminous, its perceived color depends on other factors.

Opaque Objects Suppose white light strikes an Emirati flag. The blue background absorbs all wavelengths of light except blue. The blue wavelengths reflect back to your eye. The red stripes absorb all colors but red, and red reflects to your eye. The white stars and stripes reflect all colors. You see white. An opaque object is the color it reflects, as shown in **Figure 19**.

Transparent and Translucent Objects If you look at a white lightbulb through a filter of red plastic wrap, only red wavelengths are transmitted through the plastic. The red plastic absorbs other wavelengths. Therefore, the lightbulb appears to be red.

Key Concept Check

6. How does light interact with matter?

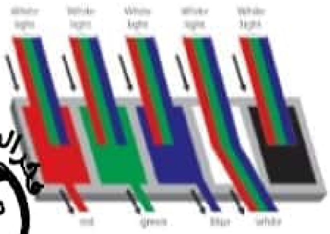


Figure 19 The color of an opaque object is the color of the light that reflects off the object. White objects reflect all colors of light. Black objects absorb all colors. Common black objects are visible because they actually reflect a small amount of light.

Speed, Wavelength, and Frequency

Remind students that speed, wavelength, and frequency are properties of waves that help describe them. Have students read the first three paragraphs. On chart paper or on the board, list the range of wavelengths in nanometers for the colors of the visible light spectrum; violet—400 nm, indigo—445 nm, blue—475 nm, green—510 nm, yellow—570 nm, orange—590 nm, and red—650 nm. **Ask:** **How is color related to the wavelength of light?** *Colors near the red end of the spectrum have the longest wavelengths. Colors near the violet end of the spectrum have the shortest wavelengths.*

Light and Matter Interact

Bring a transparent, an opaque, and a reflective object to class. Explain that the objects will help them understand how light waves interact with matter.

Transmission

Hold up the transparent object and have students describe what they see. Explain that the object is clear or transparent. Then have students read the next paragraph on this page. **Ask:** **How does the object transmit light waves?** *The light waves pass through and enable you to see what's behind it.*

Absorption

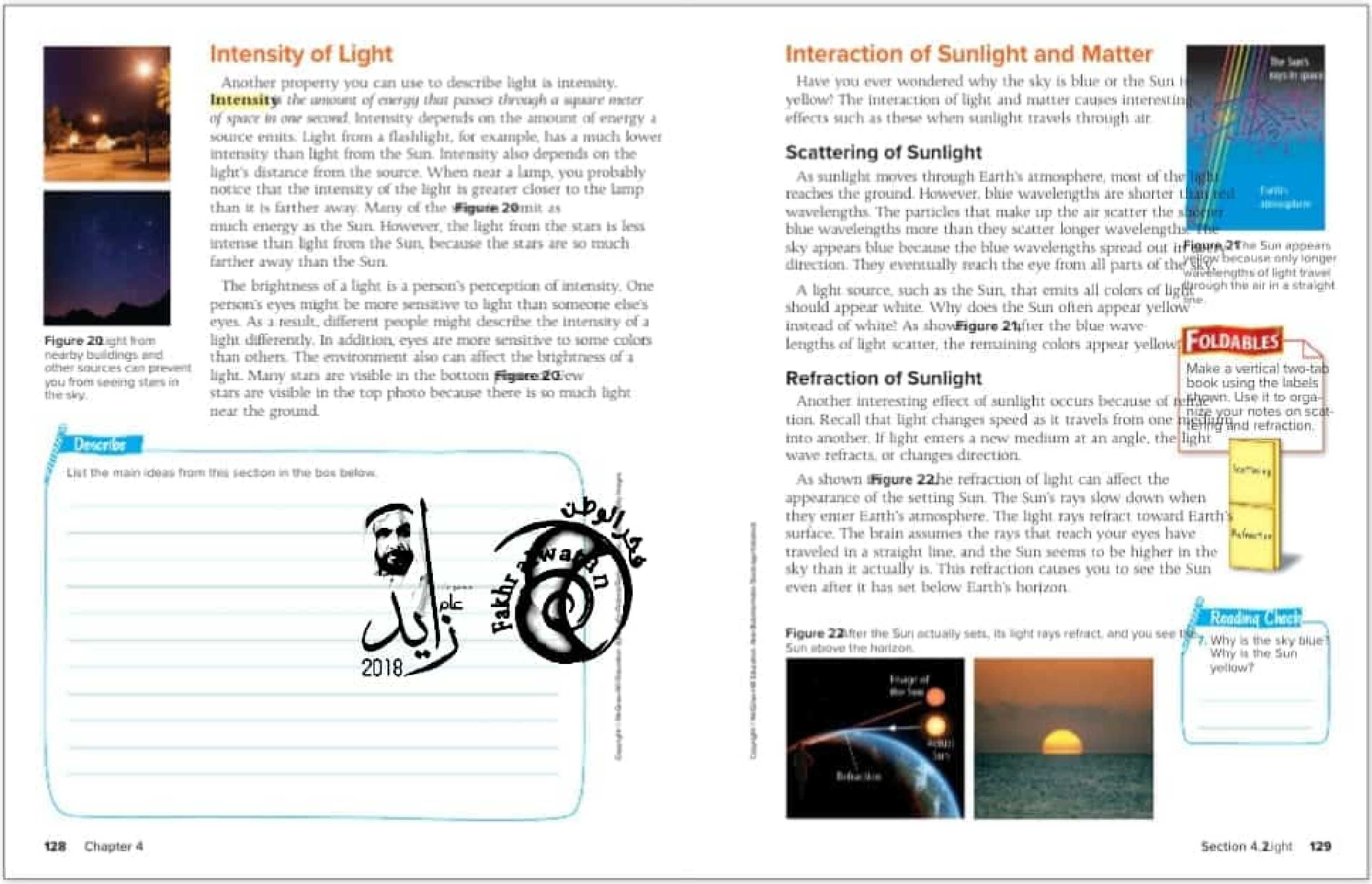
Hold up the opaque object and have students describe what they see. Explain that the object is opaque. Then have students read the next paragraph on this page. **Ask:** **How does the object absorb light waves?** *It absorbs most of the light waves and you can't see through it. Some of the energy is reflected but none is transmitted.*

Visual Literacy: Interactions of Light and Matter

Have students compare the transparent, translucent, and opaque objects shown in **Figure 18**. Ask these questions.

Guiding Questions

How does a transparent object interact with light?	*A transparent object transmits almost all the light that strikes it, enabling you to see through it.*
How does a translucent object interact with light?	*A translucent object transmits some of the light that strikes it, enabling you to see through it, but the image is blurry.*
How does an opaque object interact with light?	*An opaque object does not transmit the light that strikes it, and you can't see through it.*



Intensity of Light

Another property you can use to describe light is intensity. **Intensity** is *the amount of energy that passes through a square meter of space in one second.* Intensity depends on the amount of energy a source emits. Light from a flashlight, for example, has a much lower intensity than light from the Sun. Intensity also depends on the light's distance from the source. When near a lamp, you probably notice that the intensity of the light is greater closer to the lamp than it is farther away. Many of the **Figure 20** emit as much energy as the Sun. However, the light from the stars is less intense than light from the Sun, because the stars are so much farther away than the Sun.

The brightness of a light is a person's perception of intensity. One person's eyes might be more sensitive to light than someone else's eyes. As a result, different people might describe the intensity of a light differently. In addition, eyes are more sensitive to some colors than others. The environment also can affect the brightness of a light. Many stars are visible in the bottom **Figure 20** Few stars are visible in the top photo because there is so much light near the ground.

Figure 20 Light from nearby buildings and other sources can prevent you from seeing stars in the sky.

Describe

List the main ideas from this section in the box below.

Interaction of Sunlight and Matter

Have you ever wondered why the sky is blue or the Sun is yellow? The interaction of light and matter causes interesting effects such as these when sunlight travels through air.

Scattering of Sunlight

As sunlight moves through Earth's atmosphere, most of the light reaches the ground. However, blue wavelengths are shorter than red wavelengths. The particles that make up the air scatter the shorter blue wavelengths more than they scatter longer wavelengths. The sky appears blue because the blue wavelengths spread out in **Figure 21** direction. They eventually reach the eye from all parts of the sky.

A light source, such as the Sun, that emits all colors of light should appear white. Why does the Sun often appear yellow instead of white? As shown **Figure 21** after the blue wavelengths of light scatter, the remaining colors appear yellow.

Figure 21 The Sun appears yellow because only longer wavelengths of light travel through the air in a straight line.

FOLDABLES

Make a vertical two-tab book using the labels shown. Use it to organize your notes on scattering and refraction.

Refraction of Sunlight

Another interesting effect of sunlight occurs because of refraction. Recall that light changes speed as it travels from one medium into another. If light enters a new medium at an angle, the light wave refracts, or changes direction.

As shown **Figure 22** the refraction of light can affect the appearance of the setting Sun. The Sun's rays slow down when they enter Earth's atmosphere. The light rays refract toward Earth's surface. The brain assumes the rays that reach your eyes have traveled in a straight line, and the Sun seems to be higher in the sky than it actually is. This refraction causes you to see the Sun even after it has set below Earth's horizon.

Figure 22 After the Sun actually sets, its light rays refract, and you see the Sun above the horizon.

Reading Check

7. Why is the sky blue? Why is the Sun yellow?

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Intensity of Light

Have students compare and contrast the photos in **Figure 20.** Explain that intensity describes the brightness of a light wave. After students read the paragraphs, ask these questions.

Guiding Questions

OL Name one thing that could affect a person's perception of the intensity of light.	*sample answers: distance to the light source, sensitivity of the person's eyes*
BL How could you increase the intensity of a flashlight beam?	*You could increase the amount of energy that the beam carries.*

Interaction of Sunlight and Matter

Matter can transmit, absorb, or reflect sunlight. Explain that sunlight can interact with matter in other ways. Then have students read the first paragraph on this page.

Scattering of Sunlight

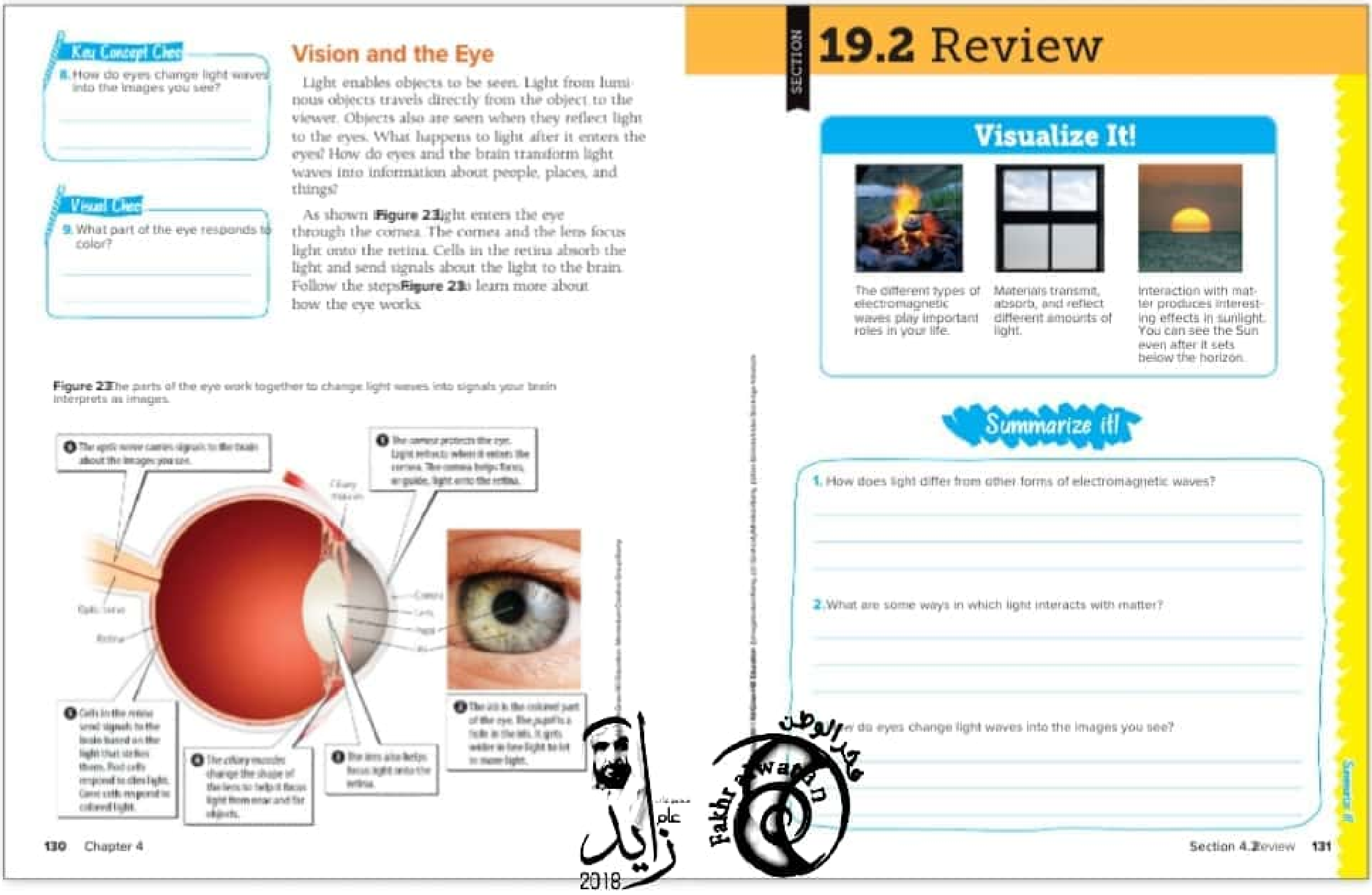
Write the word scattering on chart paper or on the board. Ask a student to look up the word in the dictionary. Ask them to predict how scattering might relate to light. Have students read the next two paragraphs and study **Figure 21.**

Guiding Questions

AL How do blue wavelengths of sunlight interact with particles in the air?	*The blue light bounces off the particles and scatters in different directions.*
OL Why is the sky blue? Why is the Sun yellow?	*The sky is blue because particles in air scatter blue wavelengths of sunlight. The Sun appears yellow because, after the blue wavelengths scatter, the remaining colors together appear yellow.*
BL Particles in air also scatter violet and indigo wavelengths but the sky does not appear dark blue or purple during the day. What might you infer about human eyes and indigo and violet wavelengths?	*Human eyes are probably less sensitive to indigo and violet wavelengths and have a harder time seeing them in the sky.*

Refraction of Sunlight

Have students read the last two paragraphs and study the photos in **Figure 22.** Explain that the refraction of light in the atmosphere also helps explain why stars seem to twinkle. Starlight refracts as it enters Earth's atmosphere. Due to the constantly changing conditions of Earth's atmosphere, the star's position seems to fluctuate, which makes it twinkle.



Key Concept Check

8. How do eyes change light waves into the images you see?

Visual Check

9. What part of the eye responds to color?

Vision and the Eye

Light enables objects to be seen. Light from luminous objects travels directly from the object to the viewer. Objects also are seen when they reflect light to the eyes. What happens to light after it enters the eyes? How do eyes and the brain transform light waves into information about people, places, and things?

As shown in **Figure 23**, light enters the eye through the cornea. The cornea and the lens focus light onto the retina. Cells in the retina absorb the light and send signals about the light to the brain. Follow the steps in **Figure 23** to learn more about how the eye works.

Figure 23 The parts of the eye work together to change light waves into signals your brain interprets as images.

130 Chapter 4

SECTION **19.2** Review

Visualize It!

The different types of electromagnetic waves play important roles in your life.

Materials transmit, absorb, and reflect different amounts of light.

Interaction with matter produces interesting effects in sunlight. You can see the Sun even after it sets below the horizon.

Summarize it!

1. How does light differ from other forms of electromagnetic waves?

2. What are some ways in which light interacts with matter?

...w do eyes change light waves into the images you see?

Section 4.2 Review 131

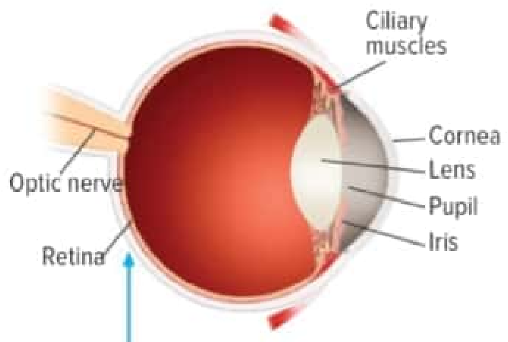
Visual Literacy: The Eye

Discuss the parts of the eye in **Figure 23**. Note that light enters through the pupil. When the eyelid covers the pupil, no light enters. Ask these questions and discuss the structures of the eye.

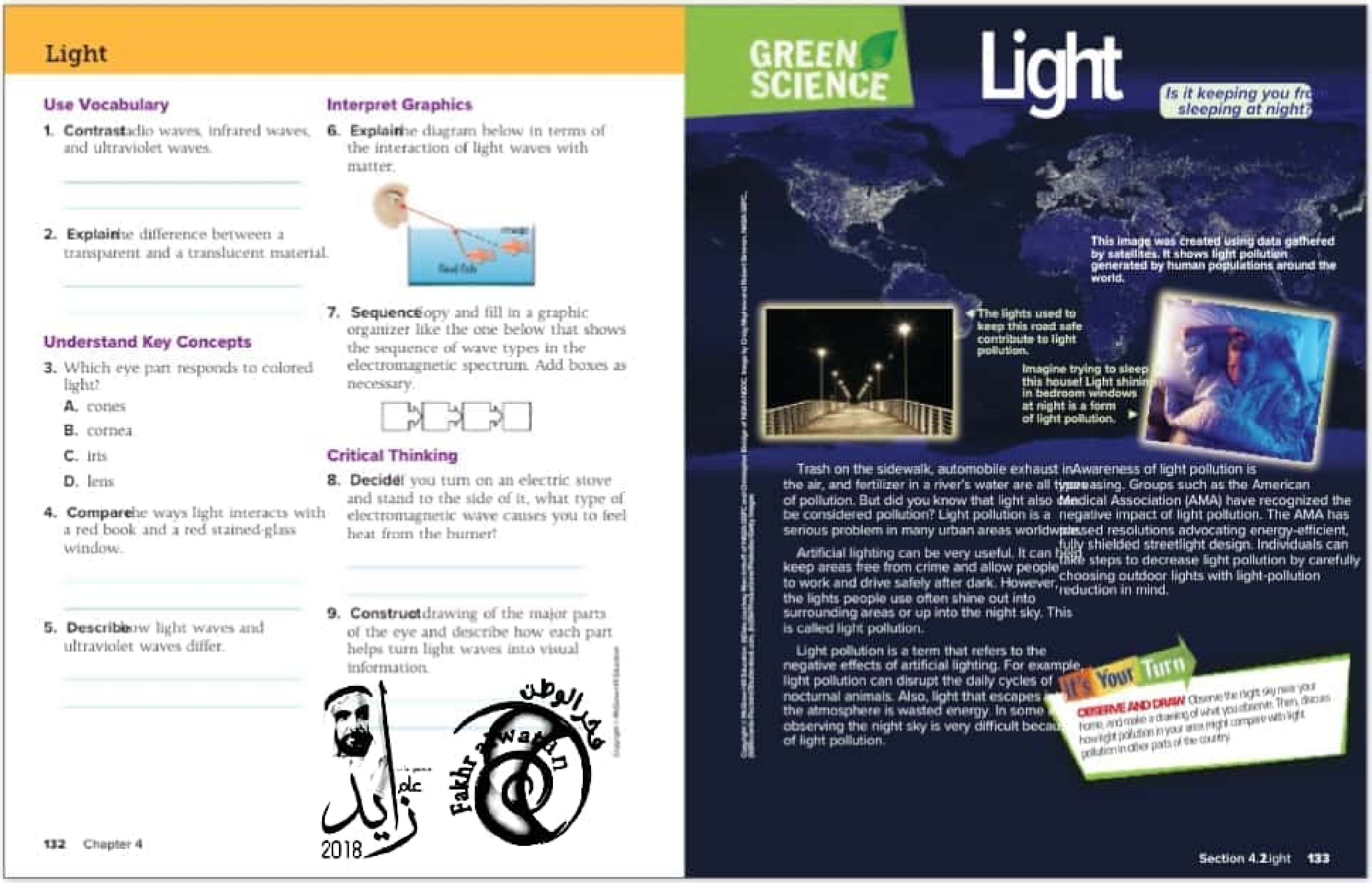
Ask: Why isn't the cornea or lens visible in the photograph of the eye? *The cornea is clear and thus invisible. The lens is behind the pupil on the inside of the eye.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**



Ask: What part of the eye responds to color? *Cone cells*



Light

Use Vocabulary

1. Contrast radio waves, infrared waves, and ultraviolet waves.

2. Explain the difference between a transparent and a translucent material.

Understand Key Concepts

3. Which eye part responds to colored light?
A. cones
B. cornea
C. iris
D. lens

4. Compare the ways light interacts with a red book and a red stained-glass window.

5. Describe how light waves and ultraviolet waves differ.

Interpret Graphics

6. Explain the diagram below in terms of the interaction of light waves with matter.

7. Sequence Copy and fill in a graphic organizer like the one below that shows the sequence of wave types in the electromagnetic spectrum. Add boxes as necessary.

Critical Thinking

8. Decide If you turn on an electric stove and stand to the side of it, what type of electromagnetic wave causes you to feel heat from the burner?

9. Construct a drawing of the major parts of the eye and describe how each part helps turn light waves into visual information.

132 Chapter 4

GREEN SCIENCE

Light

Is it keeping you from sleeping at night?

This image was created using data gathered by satellites. It shows light pollution generated by human populations around the world.

The lights used to keep this road safe contribute to light pollution.

Imagine trying to sleep in this house! Light shining in bedroom windows at night is a form of light pollution.

Trash on the sidewalk, automobile exhaust in the air, and fertilizer in a river's water are all types of pollution. But did you know that light also can be considered pollution? Light pollution is a serious problem in many urban areas worldwide.

Artificial lighting can be very useful. It can help keep areas free from crime and allow people to work and drive safely after dark. However, the lights people use often shine out into surrounding areas or up into the night sky. This is called light pollution.

Light pollution is a term that refers to the negative effects of artificial lighting. For example, light pollution can disrupt the daily cycles of nocturnal animals. Also, light that escapes into the atmosphere is wasted energy. In some areas, observing the night sky is very difficult because of light pollution.

Awareness of light pollution is increasing. Groups such as the American Medical Association (AMA) have recognized the negative impact of light pollution. The AMA has passed resolutions advocating energy-efficient, fully shielded streetlight design. Individuals can take steps to decrease light pollution by carefully choosing outdoor lights with light-pollution reduction in mind.

It's Your Turn

OBSERVE AND DRAW Observe the night sky near your home, and make a drawing of what you observe. Then, discuss how light pollution in your area might compare with light pollution in other parts of the country.

Section 4.2 Light 133

Use Vocabulary

1. Radio waves have the longest wavelengths, lowest frequencies, and lowest energy of all electromagnetic waves. Infrared waves have wavelengths just longer than light and can be sensed as thermal energy. Ultraviolet waves have shorter wavelengths, higher frequencies, and more energy than light, and they can pass through and damage skin.

2. You can see images clearly through a transparent substance, but images look blurry through a translucent substance.

Understand Key Concepts

3. A. cones

4. With the red book, all wavelengths of light are absorbed except red, which reflects off it. A red stained glass window absorbs almost all wavelengths of light except red. The red wavelengths are both transmitted and reflected, so the window looks red from both sides.

5. Light waves have a longer wavelength, lower frequency, and less energy than ultraviolet waves.

Interpret Graphics

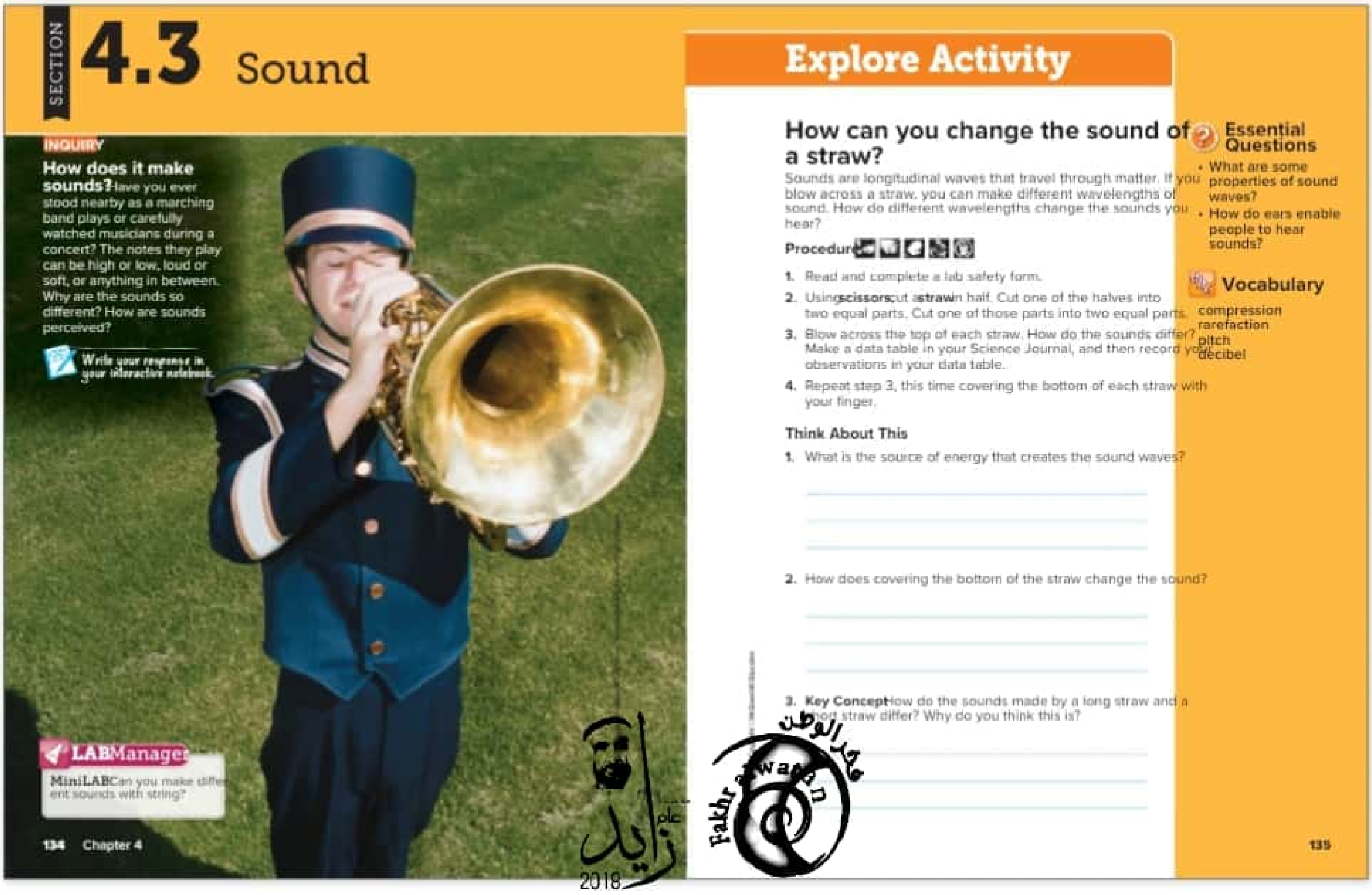
6. Light rays from the fish refract away from the normal as they move from the water into the air. The person perceives the rays as having come along a straight line, from the place where the image appears.

7. radio waves, microwaves, infrared waves, light, ultraviolet, X-rays, gamma rays

Critical Thinking

8. infrared waves.

9. Diagrams should be similar to **Figure 23** and contain the same information.



SECTION **4.3** Sound

INQUIRY

How does it make sounds? Have you ever stood nearby as a marching band plays or carefully watched musicians during a concert? The notes they play can be high or low, loud or soft, or anything in between. Why are the sounds so different? How are sounds perceived?

Write your response in your interactive notebook.

LABManager

MiniLAB Can you make different sounds with string?

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Explore Activity

How can you change the sound of a straw?

Sounds are longitudinal waves that travel through matter. If you blow across a straw, you can make different wavelengths of sound. How do different wavelengths change the sounds you hear?

Procedure

1. Read and complete a lab safety form.
2. Using **scissors**, cut a **straw** in half. Cut one of the halves into two equal parts. Cut one of those parts into two equal parts.
3. Blow across the top of each straw. How do the sounds differ? Make a data table in your Science Journal, and then record your observations in your data table.
4. Repeat step 3, this time covering the bottom of each straw with your finger.

Think About This

1. What is the source of energy that creates the sound waves?
2. How does covering the bottom of the straw change the sound?
3. **Key Concept** How do the sounds made by a long straw and a short straw differ? Why do you think this is?

Essential Questions

- What are some properties of sound waves?
- How do ears enable people to hear sounds?

Vocabulary

compression
rarefaction
pitch
decibel

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INQUIRY

About the Photo **How does it make sound?** Have students brainstorm a list of musical instruments, such as a piano, guitar, drums, saxophone, and so on. Remind them that vibrations produce waves, including sound waves. Then ask students to predict how each type of instrument they name vibrates to make music. For example, when you hit a drum, the skin vibrates and produces sound. To play a guitar or a piano, you pluck or strike the instrument's strings, which vibrate. When you play a woodwind instrument, such as a saxophone, the reed in the mouthpiece vibrates as you blow across it.

Guiding Questions

AL How do instruments make sounds?	*Instruments create vibrations in different ways to create sound waves.*
OL Why do you think different instruments produce different sounds?	*Different instruments vibrate in different ways and produce different sounds as a result.*
BL Why do you think certain instruments, such as strings, percussion, or woodwinds, are grouped together in orchestras?	*Instruments are grouped together because they vibrate in the same way and produce similar sounds as a result.*

Essential Questions

After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Compound Words

Predict How Terms Relate to the Photo

1. Write the four vocabulary words on the board.
2. Have students describe what is happening in the photo and ask them to read the caption.
3. Ask them to make predictions that explain how the four vocabulary words might relate to the image of the trumpet player.
4. To help with the predictions, guide students to connect the explanation from the caption to the sounds produced by the trumpet player. **Ask: Which words from the caption might be linked to vocabulary words?** Students might mention high and low sounds, and loud or soft sounds. **Ask: How might a sound that is high differ from a sound that is low? How might a sound that is loud compare to a sound that is soft?** Encourage students to answers these questions by making low soft sounds, then high loud sounds.

Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

What are sound waves?

Just as light is a type of wave that can be seen, sounds are a type of wave that can be heard. Sound waves are longitudinal mechanical waves. Unlike light waves, sound waves must travel through a medium.

Audible Vibrations

Suppose you strike two metal pans together. Now, suppose you strike two pillows together. How would the two sounds differ? Sound waves are vibrations the ear can detect. You hear a loud sound when you hit the pans together because they vibrate so much. You barely hear the pillows because they vibrate so little. Healthy, young humans can hear sound waves produced by vibrations with frequencies between about 20 Hz and 20,000 Hz. As people age, their ability to hear the higher and lower frequencies of sound decreases. The human ear is most sensitive to frequencies between 1,000 Hz and 4,000 Hz.

Animals have ranges of hearing that help them catch prey or avoid predators. For example, elephants hear sounds as low as 15 Hz. Chickens hear sounds between 125 Hz and 2,000 Hz. Porpoises can hear sounds between 75 Hz and 150,000 Hz! Ranges of other animals are listed in **Figure 24**.

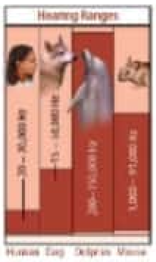


Figure 24 People and animals hear different ranges of sound frequencies.

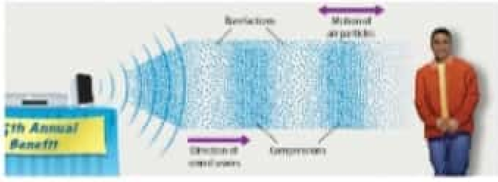


Figure 25 A sound wave produces compressions and rarefactions as it passes through matter.

Compressions and Rarefactions

Sound waves usually travel to your ears through air. Air particles are in constant motion. As the particles bounce off objects, they exert a force, or pressure. **Figure 25** shows how sound waves moving through air change the air pressure by causing air particles to move toward and then away from each other.

Suppose you pluck a guitar string. As the string springs back, it pushes air particles forward, forcing them closer together. This increases the air pressure near the string. A **compression** is *the region of a longitudinal wave where the particles of the medium are closest together.* As the string vibrates, it moves in the other direction. This leaves behind a region with lower pressure. A **rarefaction** is *the region of a longitudinal wave where the particles are farthest apart.*

Properties of Sound Waves

A sound wave is described by its wavelength, frequency, amplitude, and speed. These properties of sound waves depend on the compressions and rarefactions of the sound wave.

Wavelength, Frequency, and Pitch

... the wavelength of a wave ... shorter as the wave's frequency increases. How does the frequency of a sound wave affect what is heard?

The perception of how high or low a sound seems is called **pitch**. The higher the frequency, the higher the pitch of the sound. For example, a female voice generally produces higher-pitched sounds than a male voice. This is because the female voice has a higher range of frequencies. **Figure 26** shows the range of frequencies produced by several instruments and voices.

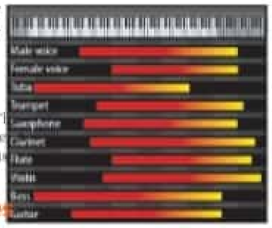


Figure 26 People and instruments have different ranges of sound frequencies.

Reading Check

4. How do compressions and rarefactions differ?

What are sound waves?

Audible Vibrations

Remind students that a mechanical wave travels through a medium— a solid, a liquid, or a gas. Before students read **Audible Vibrations**, hold the rubber band taut, then pluck it. As it vibrates, it produces sound waves. Human can hear waves within 20–20,000 Hz. **Ask: Why do you hear a loud sound if you drop a book onto a wooden floor but not if you drop the book onto a pillow?** *The same amount of energy causes the wood floor to vibrate more than the pillow; therefore, the sound is greater.*

Compressions and Rarefactions

Remind students that sound waves are longitudinal waves, which means the disturbance moves parallel to the wave's direction. Have them read the paragraphs and **Figure 25.**

Guiding Questions

AL What is a compression? What is a rarefaction?	*A compression is the part of a longitudinal wave where the particles are closest together. A rarefaction is the part of a longitudinal wave where the particles are farthest apart.*
OL How do compressions and rarefactions differ?	*Pressure is greater than normal in a compression but lower in a rarefaction.*
BL How do you think the compressions and rarefactions in sound waves change as the energy increases?	*The pressure in a compression becomes even greater and the pressure in a rarefaction becomes even lower.*

Properties of Sound Waves

Wavelength, Frequency, and Pitch

Review the properties of waves (wavelength, frequency, speed, and amplitude). Before reading the remainder of the page, discuss students' experiences in the Launch Lab, and how sounds change as the length of the straw changed.

Amplitude and Energy

You use more energy to shout than to whisper. The more energy you put into your voice, the farther the particles of air move as they vibrate. The distance a vibrating particle moves from its **rest position** is the amplitude. The more energy used to produce the sound wave, the greater the amplitude.

Speed

Sound waves travel much slower than electromagnetic waves. With sound, the transmitted energy must pass from particle to particle. The type of medium and the temperature affect the speed of sound.

Type of Medium Gas particles are far apart and collide less often than particles in a liquid or a solid. As shown in **Table 3**, a gas takes longer to transfer sound energy between particles.

Temperature Particles move faster and collide more often as the temperature of a gas increases. This increase in the number of collisions transfers more energy in less time. Temperature has the opposite effect on liquids and sounds. As liquids and solids cool, the molecules move closer together. They collide more often and transfer energy faster.

Science Use v. Common Use

rest position

Science Use position of an undisturbed particle; particles are still in motion here

Common Use the state of something not moving

Table 3 The Speed of Sound

Material	Speed (m/s)
Air (0°C)	331
Air (20°C)	343
Water (20°C)	1,481
Water (0°C)	1,500
Seawater (25°C)	1,533
Ice (0°C)	3,500
Iron	5,130
Glass	5,640

Key Concept Check

5. What are some properties of sound waves?

Describe

List the main ideas from this section in the box below.

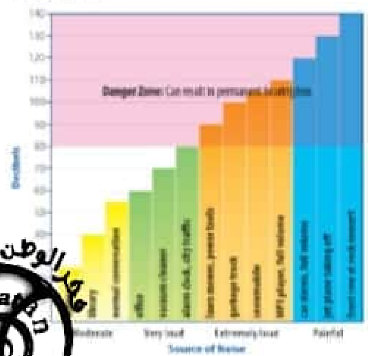
Intensity and Loudness

Generally, the greater the amplitude of a sound wave, the louder the sound seems. But what happens if you move away from a sound source? As you move away, the wave's amplitude decreases and the sound seems quieter. This is because as a sound wave moves farther from the source, more and more particles collide, and the energy from the wave spreads out among more particles. Therefore, the farther you move from the source, the less energy present in the same area of space. Recall that the amount of energy that passes through a square meter of space in one second is the intensity of a wave. Loudness is your ear's perception of intensity.

The Decibel Scale

The unit used to measure sound intensity, or loudness, is the **decibel (dB)**. The decibel levels of common sounds are shown in **Figure 27**. Each increase of 10 dB causes a sound about twice as loud. As the decibel level goes up, the amount of time you can listen to the sound without risking hearing loss gets shorter and shorter. People who work around loud sounds wear protective hearing devices to prevent hearing loss.

Figure 27 The decibel scale helps you understand safe limits of different types of sounds.



Math Skills

Use a Fraction

Because sound energy travels out in all directions from the source, the intensity of the sound decreases as you move away. You can calculate the fraction by which the sound intensity changes. The fraction $\left(\frac{r_1}{r_2}\right)^2$, where r_1 is the starting distance and r_2 is the ending distance from the source. For example, by what fraction does sound intensity decrease if you move from 3 m to 6 m from a source?

1. Replace the variables with given values.
fraction $= \left(\frac{3}{6}\right)^2$
2. Solve the problem.
$\left(\frac{3}{6}\right)^2 = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$, so the intensity decreases to $\frac{1}{4}$ of its original value.

Practice

You are standing at a distance of 2 m from a sound source. How does the sound intensity change if you move to a distance of 6 m?

Word Origin

decibel

from Latin *decibus*, means "tenth"

Amplitude and Energy / Speed

Remind students that amplitude is the maximum distance a wave moves from its rest position. The greater the amplitude, the more energy a sound wave carries. Explain that sound waves travel at different speeds through different materials. Have students read the sections and study **Table 3.**

Science Use v. Common Use

rest position

Have students compare the science use of *rest position* to the common use of the term.

Ask: **According to the scientific definition, are particles in rest position still or in motion?** *motion; their rest position is their natural or starting position*

Ask: **What are some properties of sound waves?** *amplitude, energy, speed, wavelength, frequency, and pitch*

Intensity and Loudness

Recall that intensity is the amount of energy that passes through a square meter of space in one second. Remind students that intensity helps describe how bright a light appears. Ask them to predict what intensity might tell you about a sound wave. Then have students read the first paragraph.

Guiding Questions

AL	Why are sound waves softer the farther you are from the source of the sound?	*Sound waves spread out in all directions and have less energy the farther you are from the source of the sound.*
OL	What is the relationship between the amplitude and the intensity of a sound wave?	*A sound wave with a large amplitude has high intensity.*
BL	How does the energy of a sound wave help explain how loud or soft it is near the source of the sound?	*A sound wave with a lot of energy has a greater amplitude and higher intensity than a wave with less energy. It sounds loud near the source, whereas the other wave sounds soft.*

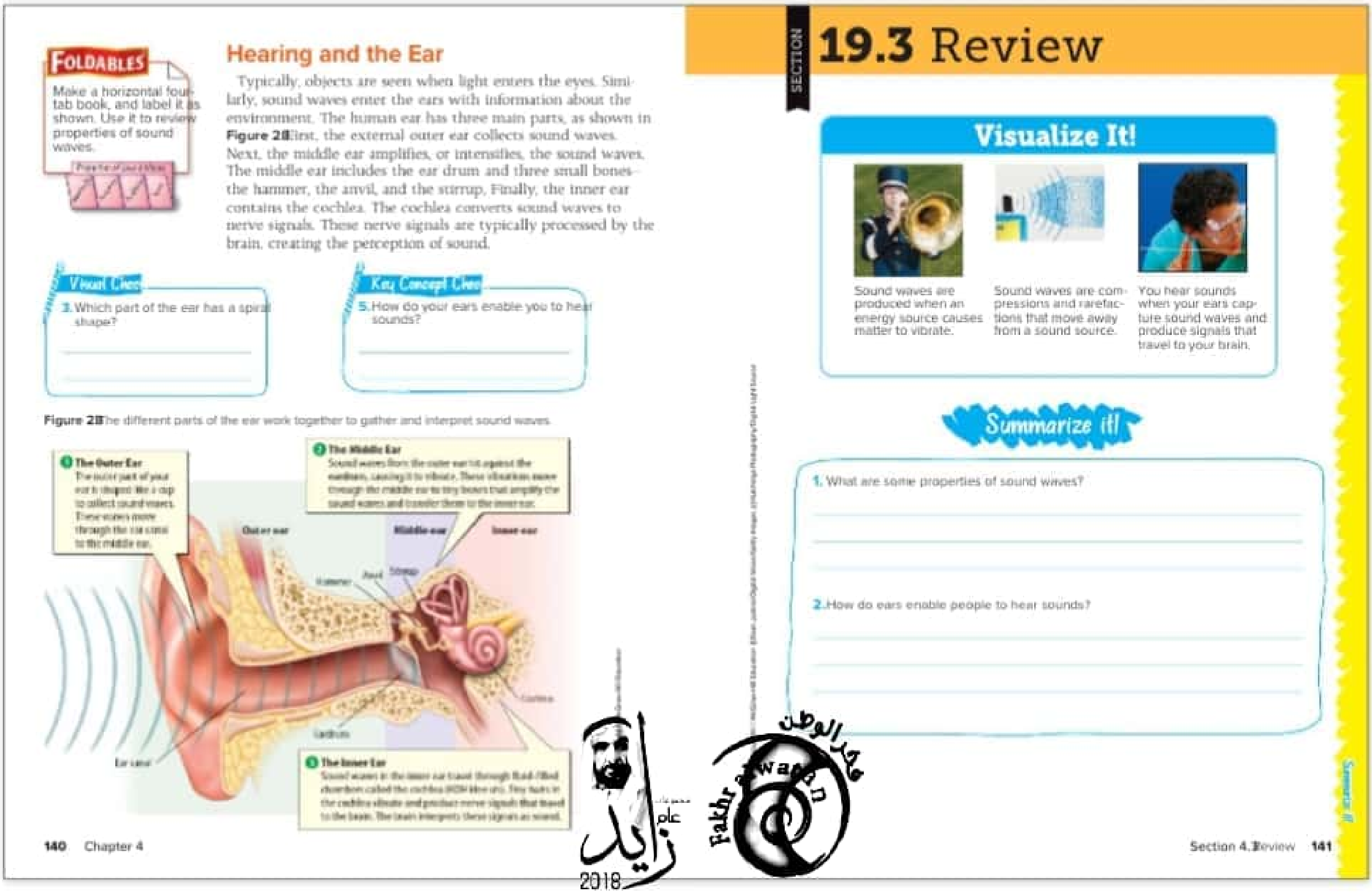
The Decibel Scale

Remind students that you can measure the amplitude or frequency of a sound wave. Explain that you also can measure its intensity. Review the word origin of *decibel* and then have students read the next paragraph.

Word Origin

decibel

Have students read the Latin origin of the term *decibel*. **Ask:** **How does the Latin origin help you understand the levels of the decibel scale?** *It tells you that the levels are in increments of 10.*



FOLDABLES

Make a horizontal four-tab book, and label it as shown. Use it to review properties of sound waves.

Hearing and the Ear

Typically, objects are seen when light enters the eyes. Similarly, sound waves enter the ears with information about the environment. The human ear has three main parts, as shown in **Figure 28**. First, the external outer ear collects sound waves. Next, the middle ear amplifies, or intensifies, the sound waves. The middle ear includes the ear drum and three small bones—the hammer, the anvil, and the stirrup. Finally, the inner ear contains the cochlea. The cochlea converts sound waves to nerve signals. These nerve signals are typically processed by the brain, creating the perception of sound.

Visual Check 3. Which part of the ear has a spiral shape?

Key Concept Check 5. How do your ears enable you to hear sounds?

Figure 28 The different parts of the ear work together to gather and interpret sound waves.

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SECTION **19.3 Review**

Visualize It!

Sound waves are produced when an energy source causes matter to vibrate.

Sound waves are compressions and rarefactions that move away from a sound source.

You hear sounds when your ears capture sound waves and produce signals that travel to your brain.

Summarize it!

1. What are some properties of sound waves?

2. How do ears enable people to hear sounds?

Section 4.3 Review 141

Hearing and the Ear

Explain that we hear because of the way our ears detect audible vibrations and our brains interpret the sound waves. Have students read the paragraphs on this page and answer these questions.

Guiding Questions

AL How does the cochlea help you hear? *The special cells in the cochlea convert sound waves into nerve signals that are interpreted by the brain.*

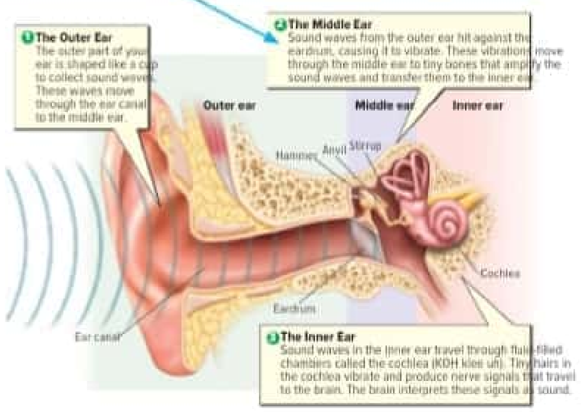
OL How do your ears enable you to hear sounds? *Your outer ear collects sound waves and transfers the vibrations to the eardrum. As the vibrations move through the ear, the ear amplifies the sound and then converts it into nerve signals, which the brain can interpret.*

BL People who need hearing aids sometimes wear them to correct problems with their cochlea. How do you think problems with the cochlea can impact a person's hearing? *The special cells in the cochlea send signals to the brain. If the cochlea were to have difficulty changing sound waves or sending these signals, it would be harder for the brain to interpret sounds; as a result, it would be harder to hear.*

Visual Literacy: Parts of the Human Ear

Have students study the diagram in **Figure 28** and identify the different parts of the ear.

Ask: **What happens to the sound waves in the middle ear and inner ear?** *Sound waves make the eardrum vibrate, which amplifies the sound and sends it to the cochlea in the inner ear. In the cochlea, sound waves are converted to nerve signals and sent to the brain.*



Sound

Use Vocabulary

1. The property of a sound wave that relates to a high or low musical note is the sound's ______.
2. **Explain** the difference between a compression and a rarefaction in a sound wave.

Understand Key Concepts

3. Which property of a sound wave describes the amount of energy that passes through a square meter of space each second?
   A. amplitude
   B. frequency
   C. intensity
   D. wavelength
4. **Describe** how the three main parts of the ear enable people to hear.

Interpret Graphics

5. **Sequence** Copy and fill in a graphic organizer like the one below to describe the path of a sound wave from when it is produced by a source until it is interpreted by the brain. Describe the function of each part of the path.

Sound produced in air → ☐ → ☐ → ☐ → Sound interpreted by the brain

Critical Thinking

6. **Construct** a diagram of four sound waves. Two of the waves should have the same amplitude but different frequencies. The other two waves should have the same wavelength but different amplitudes. Label the properties of the waves.

Math Skill

7. A student is standing a distance of 4 m from the school bell. If the student moves to a distance 20 m away, what fraction of the original intensity of the bell's sound will the student hear?

My Notes

Use Vocabulary

1. pitch
2. A compression is an area of higher pressure, where the particles are closer together. A rarefaction is an area of lower pressure, where the particles are farther apart.

Understand Key Concepts

3. C. intensity
4. The outer ear collects sound waves. The middle ear transfers and amplifies the sound waves. The inner ear changes the vibrations to nerve signals, which the brain can interpret.

Interpret Graphics

5. Sound produced in air→Outer ear collects sound waves→Middle ear amplifies the sound waves→Inner ear changes the vibrations to nerve signals→Sound interpreted by the brain.

Critical Thinking

6. Check student diagrams to be sure that they have illustrated the correct wave properties. Students should label amplitude, frequency, and wavelength.

Math Skill

7. 1/2

Intervention Plann

Based on the results of the Lesson Review, use the chart below to address individual needs.

Use Vocabulary (1–2)

TE VGuiding Questions, Compressions and Rarefactions
Visual Literacy: Frequency Related to Pitch
CR Quick Vocabulary
Content Vocabulary

Understand Key Concepts (3–4)

TE Guiding Questions, Intensity and Loudness
Visual Literacy: Parts of the Human Ear
CR Key Concept Builder

Interpret Graphics (5)

TE Visual Literacy: Parts of the Human Ear

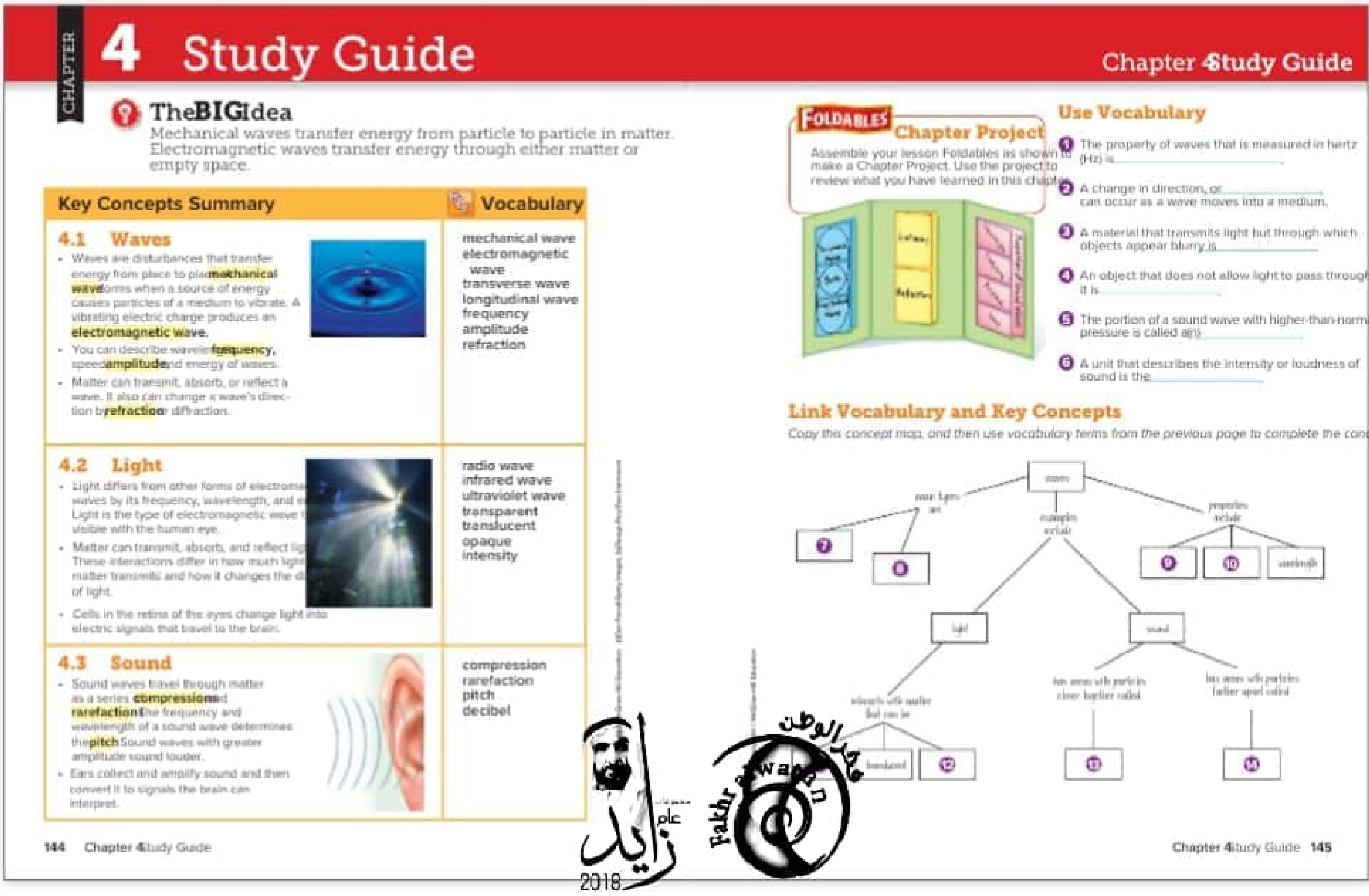
Critical Thinking (6)

TE Visual Literacy: Frequency Related to Pitch
CR Enrichment
Challenge

Math Skills (7)

TE Math Skills: Use a Fraction
CR Math Skills
Math Personal Tutor: Multiply Fractions
Math Practice: Use a Wave

Teacher Notes



CHAPTER 4 Study Guide

Chapter 4 Study Guide

TheBIGIdea

Mechanical waves transfer energy from particle to particle in matter. Electromagnetic waves transfer energy through either matter or empty space.

Key Concepts Summary	Vocabulary
4.1 Waves • Waves are disturbances that transfer energy from place to place. **mechanical wave** forms when a source of energy causes particles of a medium to vibrate. A vibrating electric charge produces an **electromagnetic wave**. • You can describe waves by frequency, speed, amplitude, and energy of waves. • Matter can transmit, absorb, or reflect a wave. It also can change a wave's direction by **refraction** or diffraction.	mechanical wave, electromagnetic wave, transverse wave, longitudinal wave, frequency, amplitude, refraction
4.2 Light • Light differs from other forms of electromagnetic waves by its frequency, wavelength, and energy. Light is the type of electromagnetic wave visible with the human eye. • Matter can transmit, absorb, and reflect light. These interactions differ in how much light matter transmits and how it changes the direction of light. • Cells in the retina of the eyes change light into electric signals that travel to the brain.	radio wave, infrared wave, ultraviolet wave, transparent, translucent, opaque, intensity
4.3 Sound • Sound waves travel through matter as a series of **compressions** and **rarefactions**. The frequency and wavelength of a sound wave determines the **pitch**. Sound waves with greater amplitude sound louder. • Ears collect and amplify sound and then convert it to signals the brain can interpret.	compression, rarefaction, pitch, decibel

FOLDABLES Chapter Project

Assemble your lesson Foldables as shown to make a Chapter Project. Use the project to review what you have learned in this chapter.

Use Vocabulary

1. The property of waves that is measured in hertz (Hz) is ______.
2. A change in direction, or ______, can occur as a wave moves into a medium.
3. A material that transmits light but through which objects appear blurry is ______.
4. An object that does not allow light to pass through it is ______.
5. The portion of a sound wave with higher-than-normal pressure is called a(n) ______.
6. A unit that describes the intensity or loudness of sound is the ______.

Link Vocabulary and Key Concepts

Copy this concept map, and then use vocabulary terms from the previous page to complete the concept map.

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Chapter 4 Study Guide 145

Key Concepts Summary	Vocabulary

Study Strategy: Check Answers to Key Concept Questions

Teach students to focus on the areas that they do not understand and to spend less time on concepts they have mastered.

1. Write the Key Concept questions from the start of each lesson on chart paper or the board.
2. Ask students to answer each question in their Science Journals.
3. Instruct students to note the questions they had a difficult time answering. Then have them compare their answers to the Key Concepts Summary in the Chapter Study Guide. Tell them to write a check beside any answers that were correct and to circle any answers that were inaccurate or incomplete.
4. Have students look through the chapter to find any information relevant to the answers they circled. Have them use this information to rewrite their answers.

Example:

A wave is a disturbance that transfers energy.

It is caused by vibrations.

Amplitude is one property of waves.

Study Strategy: Create Wave Concept Maps

Ask students to create a concept map for the different kinds of waves described in the chapter. This graphic organizer enables students to understand more about each word than just its definition.

1. Have students draw concept maps, similar to the one below, for each kind of wave. The type of wave should be in the center of the map.
2. Have students write the following questions in the surrounding bubbles on the concept map: What is it? How is it produced? What is one property of this kind of wave? What is one way this wave interacts with matter?
3. Then students should answer these questions and fill in the answers in the appropriate bubbles on the map.
4. After students complete the maps, ask them to write a comprehensive definition of each kind of wave.

Example: