Chapter 13 Energy

The BIG Idea
Energy Forms and Conservation

What is energy and how can it be transformed?

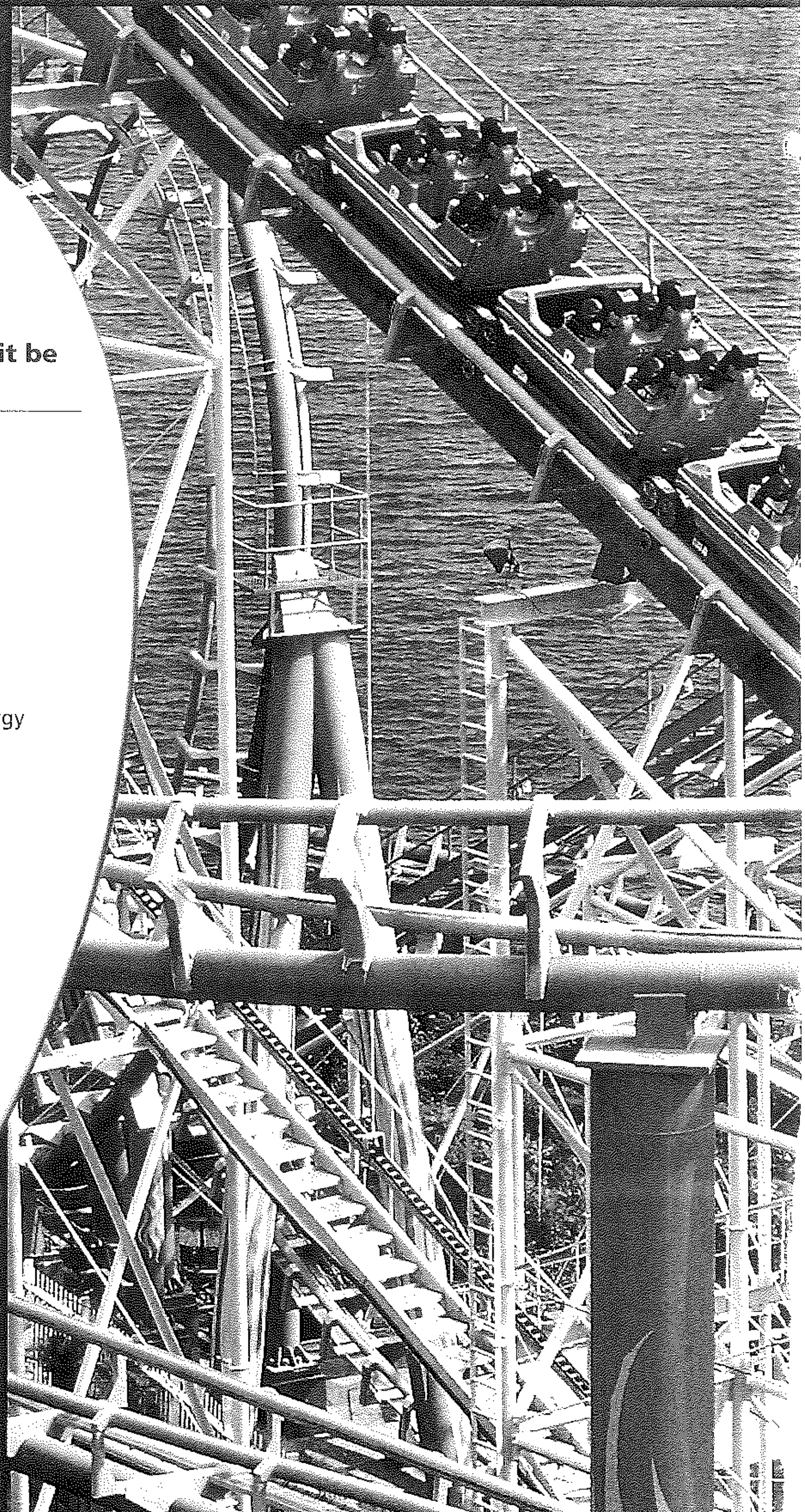
Chapter Preview

1 What Is Energy?
Discover How High Does a Ball Bounce?
Math Skills Exponents

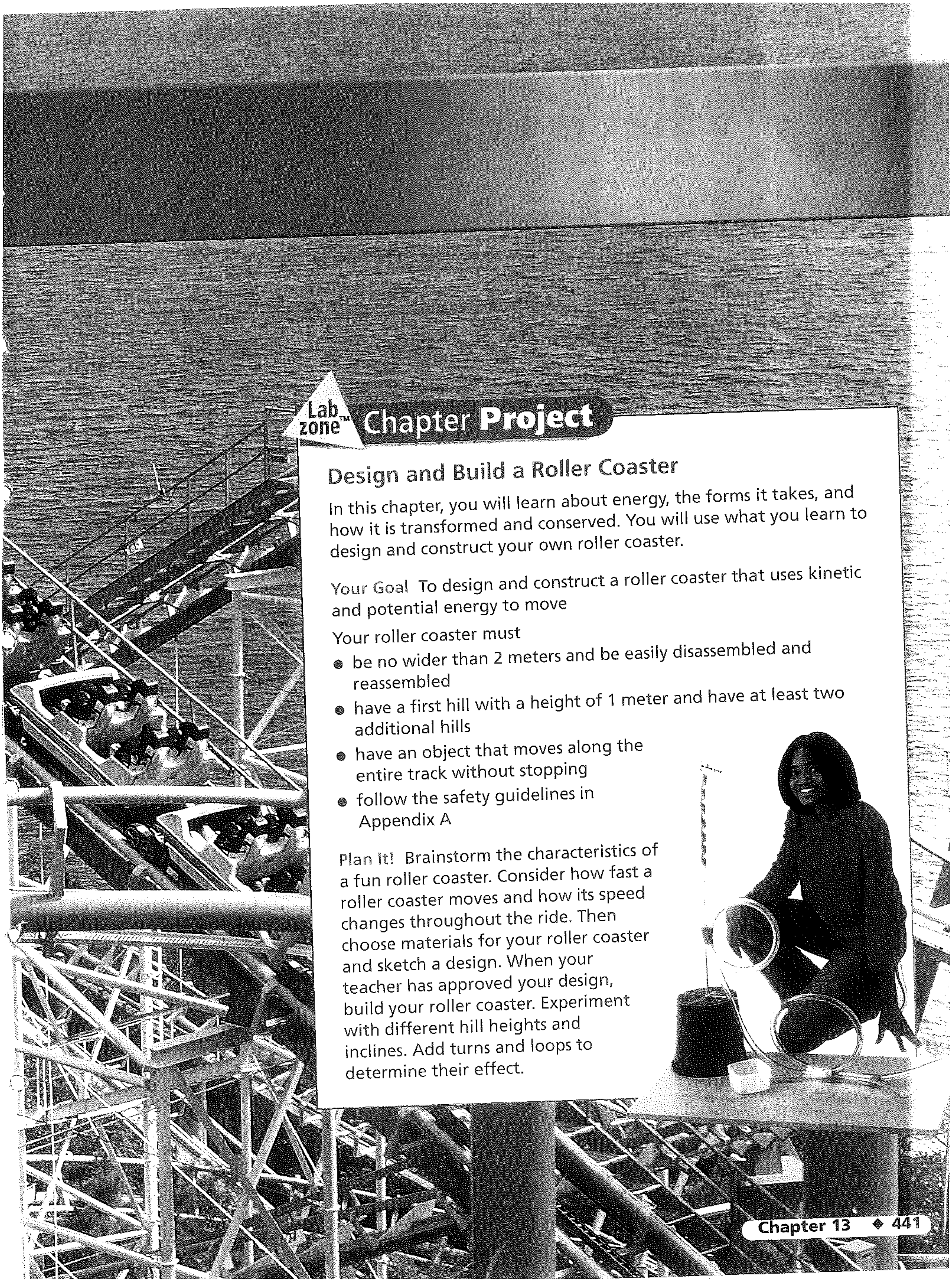
2 Forms of Energy
Discover What Makes a Flashlight Shine?
Analyzing Data Calculating Mechanical Energy
Skills Lab Can You Feel the Power?

3 Energy Transformations and Conservation
Discover What Would Make a Card Jump?
Skills Activity Classifying
Active Art Energy Transformations
Try This Pendulum Swing
At-Home Activity Hot Wire
Skills Lab Soaring Straws

4 Energy and Fossil Fuels
Discover What Is a Fuel?
Skills Activity Graphing
At-Home Activity Burning Fossils



A roller coaster with different hill heights and inclines ▶



Lab zone™ Chapter **Project**

Design and Build a Roller Coaster

In this chapter, you will learn about energy, the forms it takes, and how it is transformed and conserved. You will use what you learn to design and construct your own roller coaster.

Your Goal To design and construct a roller coaster that uses kinetic and potential energy to move

Your roller coaster must

- be no wider than 2 meters and be easily disassembled and reassembled
- have a first hill with a height of 1 meter and have at least two additional hills
- have an object that moves along the entire track without stopping
- follow the safety guidelines in Appendix A

Plan It! Brainstorm the characteristics of a fun roller coaster. Consider how fast a roller coaster moves and how its speed changes throughout the ride. Then choose materials for your roller coaster and sketch a design. When your teacher has approved your design, build your roller coaster. Experiment with different hill heights and inclines. Add turns and loops to determine their effect.

Section 1 What Is Energy?

Reading Preview

Key Concepts

- How are energy, work, and power related?
- What are the two basic kinds of energy?

Key Terms

- energy
- kinetic energy
- potential energy
- gravitational potential energy
- elastic potential energy

Target Reading Skill

Using Prior Knowledge Before you read, look at the section headings and visuals to see what this section is about. Then write what you know about energy in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. The joule is the unit of work. 2.

What You Learned
1. 2.

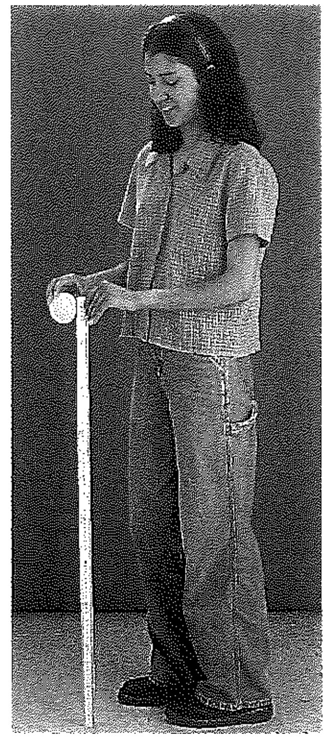
Lab zone Discover Activity

How High Does a Ball Bounce?

1. Hold a meter stick vertically, with the zero end on the ground.
2. Drop a tennis ball from the 50-cm mark and record the height to which it bounces.
3. Drop the tennis ball from the 100-cm mark and record the height to which it bounces.
4. Predict how high the ball will bounce if dropped from the 75-cm mark. Test your prediction.

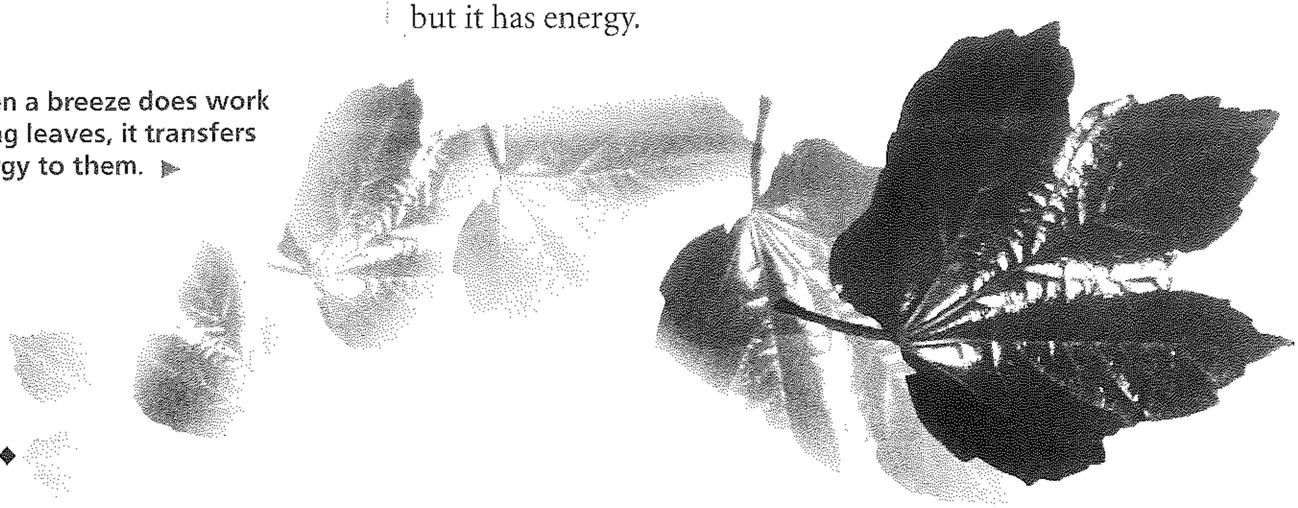
Think It Over

Observing How does the height from which you drop the ball relate to the height to which the ball bounces?



Brilliant streaks of lightning flash across the night sky. The wind howls, and thunder cracks and rumbles. Then a sound like a runaway locomotive approaches, growing louder each second. Whirling winds rush through the town. Roofs are lifted off of buildings. Cars are thrown about like toys. Then, in minutes, the tornado is gone.

The next morning, a light breeze carries leaves past the debris. The wind that destroyed buildings hours before is now barely strong enough to move a leaf. Wind is just moving air, but it has energy.



When a breeze does work lifting leaves, it transfers energy to them. ▶

Energy, Work, and Power

When wind moves a house, or even a leaf, it causes a change. In this case, the change is in the position of the object. Recall that work is done when a force moves an object through a distance. The ability to do work or cause change is called **energy.** So the wind has energy.

Work and Energy When an object or living thing does work on another object, some of its energy is transferred to that object. You can think of work, then, as the transfer of energy. When energy is transferred, the object upon which the work is done gains energy. Energy is measured in joules—the same units as work.

Power and Energy You may recall that power is the rate at which work is done. **If the transfer of energy is work, then power is the rate at which energy is transferred, or the amount of energy transferred in a unit of time.**

$$\text{Power} = \frac{\text{Energy transferred}}{\text{Time}}$$

Power is involved whenever energy is being transferred. For example, a calm breeze's power is its rate of energy transfer to lift a leaf a certain distance. The tornado in Figure 1 transfers the same amount of energy when it lifts the leaf the same distance. However, the tornado has a greater power than the breeze because it transfers energy to the leaf in less time.

Reading Checkpoint: **What is power in terms of energy?**

Kinetic Energy

Two basic kinds of energy are kinetic energy and potential energy. Whether energy is kinetic or potential depends on whether an object is moving or not.

A moving object, such as the wind, can do work when it strikes another object and moves it some distance. Because the moving object does work, it has energy. The energy an object has due to its motion is called **kinetic energy.** The word *kinetic* comes from the Greek word *kinetos,* which means "moving."

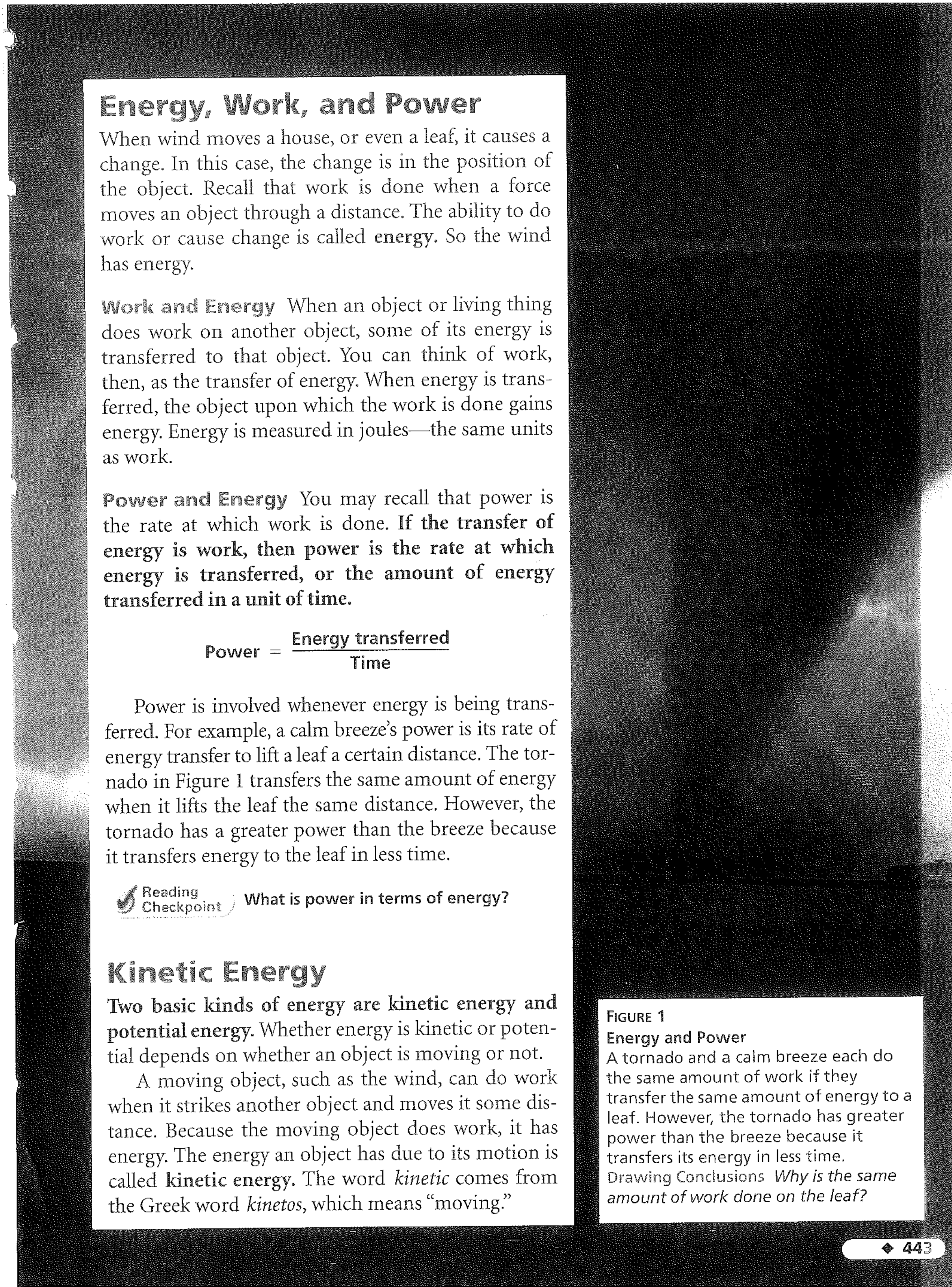


FIGURE 1
Energy and Power
A tornado and a calm breeze each do the same amount of work if they transfer the same amount of energy to a leaf. However, the tornado has greater power than the breeze because it transfers its energy in less time.
Drawing Conclusions *Why is the same amount of work done on the leaf?*

Math Skills

Exponents

An exponent tells how many times a number is used as a factor. For example, 3×3 can be written as 3^2. You read this number as "three squared." An exponent of 2 indicates that the number 3 is used as a factor two times. To find the value of a squared number, multiply the number by itself.

$$3^2 = 3 \times 3 = 9$$

Practice Problem What is the value of the number 8^2?

Factors Affecting Kinetic Energy The kinetic energy of an object depends on both its mass and its velocity. Kinetic energy increases as mass increases. For example, think about rolling a bowling ball and a golf ball down a bowling lane at the same velocity, as shown in Figure 2. The bowling ball has more mass than the golf ball. If both balls have the same velocity, the bowling ball is more likely to knock down the pins because it has more kinetic energy than the golf ball.

Kinetic energy also increases when velocity increases. For example, suppose you have two identical bowling balls and you roll one ball so it moves at a greater velocity than the other. You must throw the ball harder to give it the greater velocity. In other words, you transfer more energy to it. Therefore, the faster ball has more kinetic energy.

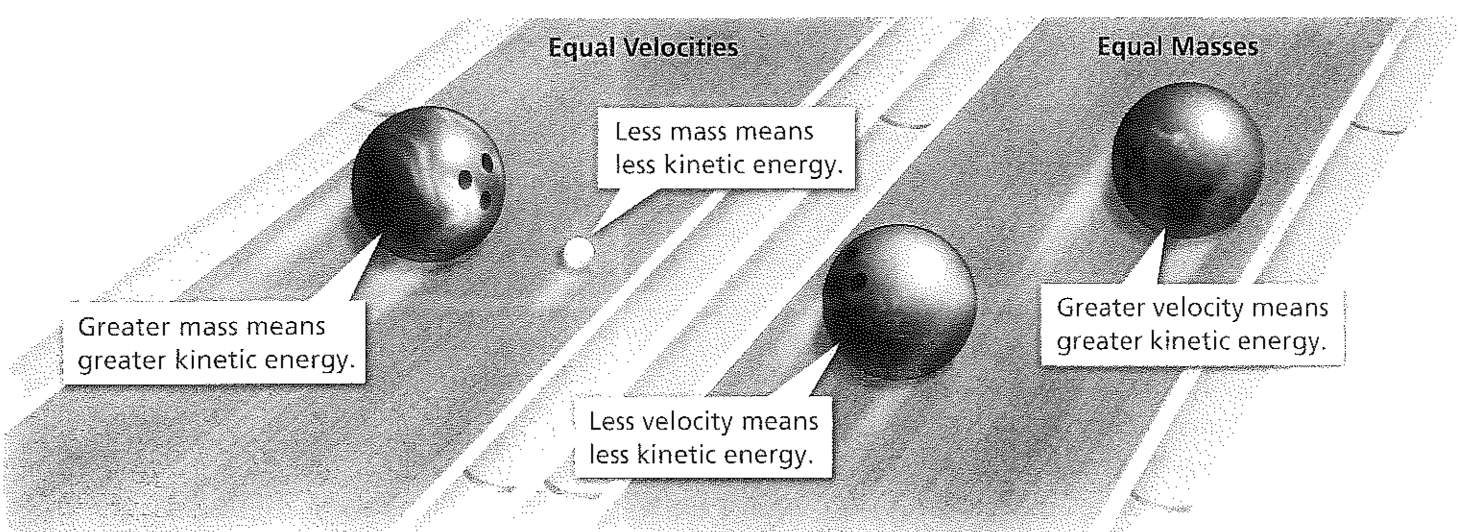
Calculating Kinetic Energy There is a mathematical relationship between kinetic energy, mass, and velocity.

$$\text{Kinetic energy} = \frac{1}{2} \times \text{Mass} \times \text{Velocity}^2$$

Do changes in velocity and mass have the same effect on kinetic energy? No—changing the velocity of an object will have a greater effect on its kinetic energy than changing its mass by the same factor. This is because velocity is squared in the kinetic energy equation. For instance, doubling the mass of an object will double its kinetic energy. But doubling its velocity will quadruple its kinetic energy.

Reading Checkpoint **Which has a greater effect on an object's kinetic energy—doubling its mass or doubling its velocity?**

FIGURE 2
Kinetic Energy
Kinetic energy increases as mass and velocity increase.
Predicting *In each example, which object will transfer more energy to the pins? Why?*



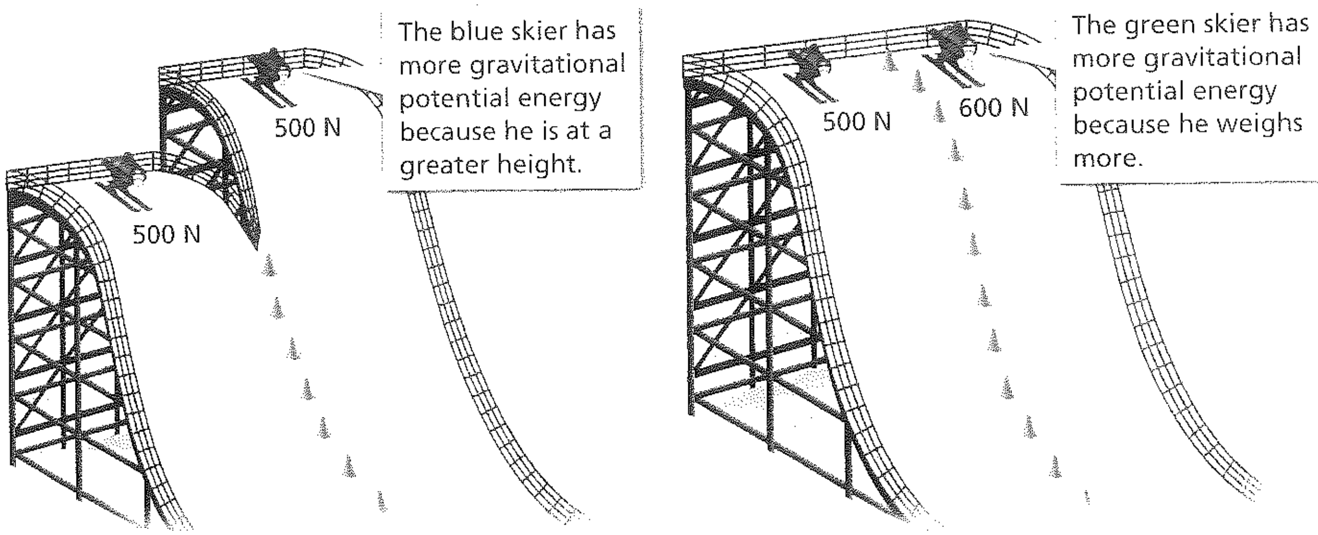


FIGURE 3
Gravitational Potential Energy
Gravitational potential energy increases as weight and height increase.
Interpreting Diagrams *Does the red skier have more gravitational potential energy on the higher ski jump or the lower one? Why?*

Potential Energy

An object does not have to be moving to have energy. Some objects have stored energy as a result of their positions or shapes. When you lift a book up to your desk from the floor or compress a spring to wind a toy, you transfer energy to it. The energy you transfer is stored, or held in readiness. It might be used later when the book falls to the floor or the spring unwinds. Stored energy that results from the position or shape of an object is called **potential energy.** This type of energy has the potential to do work.

Gravitational Potential Energy Potential energy related to an object's height is called **gravitational potential energy.** The gravitational potential energy of an object is equal to the work done to lift it. Remember that Work = Force × Distance. The force you use to lift the object is equal to its weight. The distance you move the object is its height. You can calculate an object's gravitational potential energy using this formula.

$$\text{Gravitational potential energy} = \text{Weight} \times \text{Height}$$

For example, the red skier on the left in Figure 3 weighs 500 newtons. If the ski jump is 40 meters high, then the skier has 500 newtons × 40 meters, or 20,000 J, of gravitational potential energy.

The more an object weighs, or the greater the object's height, the greater its gravitational potential energy. At the same height, a 600-newton skier has more gravitational potential energy than a 500-newton skier. Similarly, a 500-newton skier has more gravitational potential energy on a high ski jump than on a low one.

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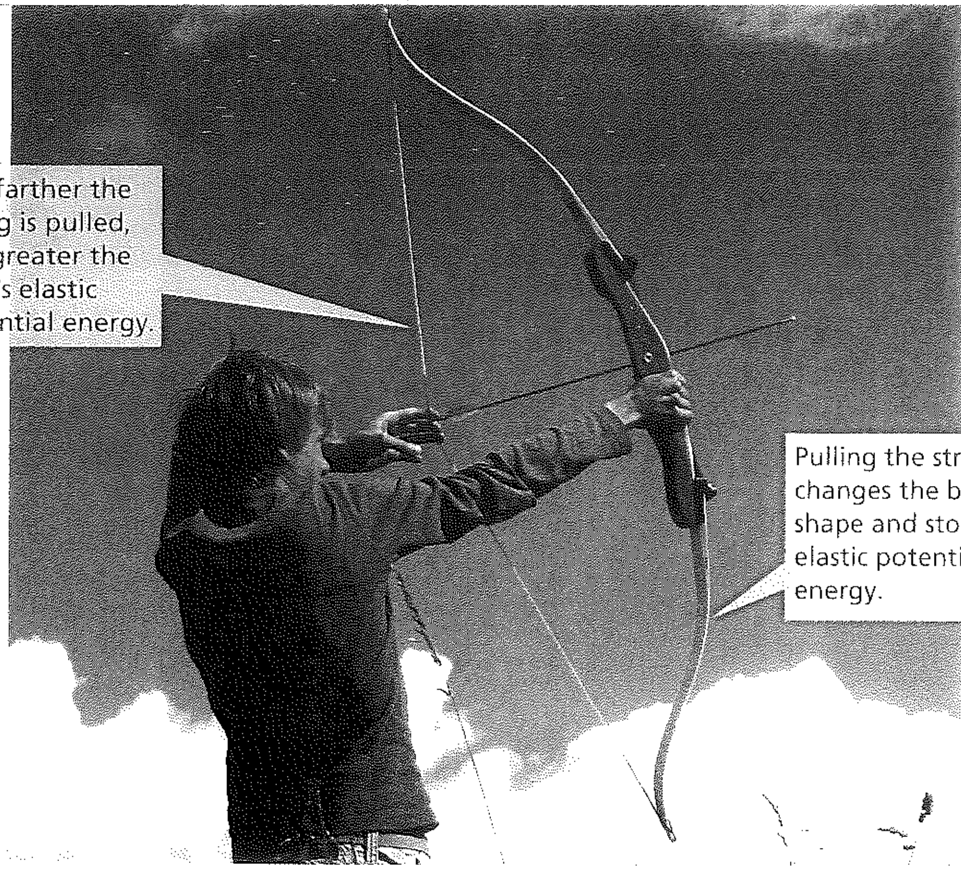


FIGURE 4
Elastic Potential Energy
The energy stored in a stretched object, such as a bow, is elastic potential energy. Interpreting Photographs *When the energy stored in the bow is released, how is it used?*

Elastic Potential Energy An object gains a different type of potential energy when it is stretched. The potential energy associated with objects that can be stretched or compressed is called **elastic potential energy.** For example, when an archer pulls back an arrow, the bow changes shape. The bow now has potential energy. When the archer releases the string, the stored energy sends the arrow flying to its target.

Reading Checkpoint **What type of energy does a bow have when you pull back an arrow?**

Section 1 Assessment

Target Reading Skill

Using Prior Knowledge Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

1. a. Defining What is energy?
   b. Describing How are energy, work, and power related?
   c. Applying Concepts If a handsaw does the same amount of work on a log as a chainsaw does, which has a greater power? Why?
2. a. Identifying What is kinetic energy? What is potential energy?
   b. Explaining What factors affect an object's kinetic energy?
   c. Problem Solving At a given height above Earth, how would you determine the potential energy of a sky diver? The kinetic energy of a sky diver?

Math Practice

3. Exponents What is the value of the number 10^2?
4. Exponents What number when squared gives you the value 36?

Section 2 Forms of Energy

Reading Preview

Key Concepts

- How can you determine an object's mechanical energy?
- What are some forms of energy associated with the particles that make up objects?

Key Terms

- mechanical energy
- thermal energy
- electrical energy
- chemical energy
- nuclear energy
- electromagnetic energy

Target Reading Skill

Building Vocabulary After you read the section, reread the paragraphs that contain definitions of Key Terms. Use the information you have learned to write a definition of each Key Term in your own words.

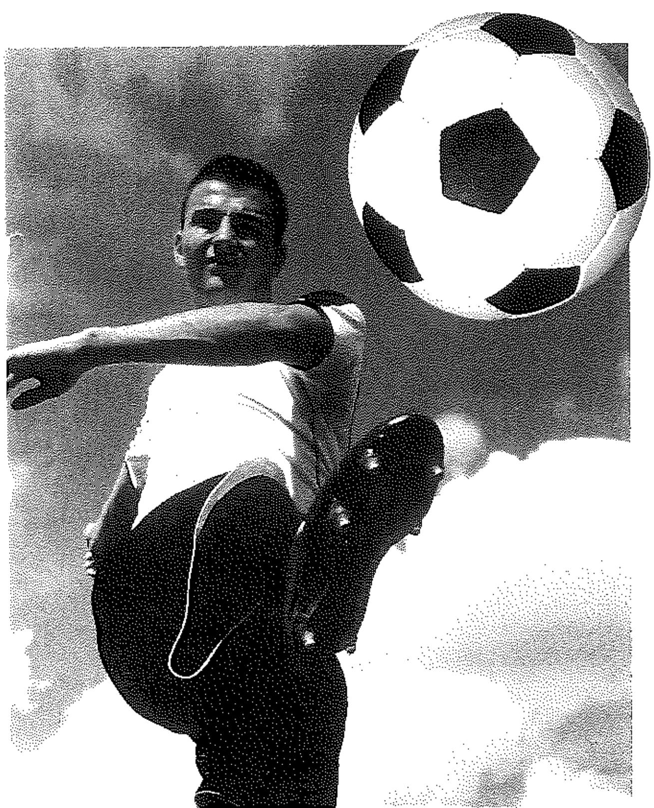
Lab zone Discover Activity

What Makes a Flashlight Shine?

1. Remove the batteries from a flashlight and examine them. Think about what type of energy is stored in the batteries.
2. Replace the batteries and turn on the flashlight. What type of energy do you observe?
3. After a few minutes, place your hand near the bulb of the flashlight. What type of energy do you feel?

Think It Over

Inferring Describe how you think a flashlight works in terms of energy. Where does the energy come from? Where does the energy go?



You are on the edge of your seat as the soccer player steps forward and then launches a deep kick. The ball soars down the field and lands in the net. The electronic scoreboard flashes GOAL! You jump to your feet and cheer!

As the crowd settles back down, you shiver. The sun is setting, and the afternoon is growing cool. A vendor hands you a hot dog, and its heat helps warm your hands. Suddenly, the stadium lights switch on. You can see the players more clearly as they line up for the next play.

The kicked soccer ball, the scoreboard, the sun, the hot dog, and the stadium lights all have energy. You have energy, too! Energy comes in many different forms.

Mechanical Energy

Think about the kick by the soccer player. A soccer ball kicked by a soccer player has mechanical energy. So does a moving car or a trophy on a shelf. The form of energy associated with the position and motion of an object is called **mechanical energy.**

◀ A soccer player transfers mechanical energy to the soccer ball.

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An object's mechanical energy is a combination of its potential energy and kinetic energy. **You can find an object's mechanical energy by adding the object's kinetic energy and potential energy.**

Mechanical Energy = Potential energy + Kinetic energy

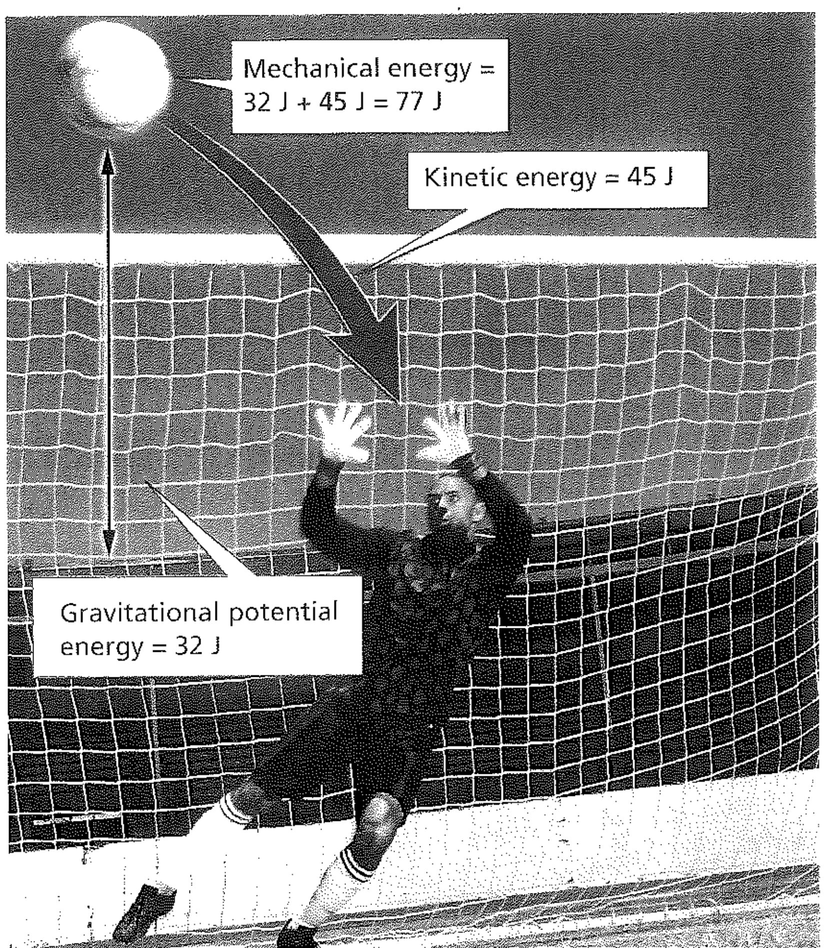
For example, a soccer ball kicked by a soccer player has both potential energy and kinetic energy. The higher the soccer ball, the greater its potential energy. The faster the soccer ball moves, the greater its kinetic energy.

You can add the potential energy and kinetic energy of the soccer ball in Figure 5 to find its mechanical energy. The soccer ball has 32 joules of potential energy due to its position above the ground. It also has 45 joules of kinetic energy due to its motion. The total mechanical energy of the football is equal to 32 joules + 45 joules, or 77 joules.

An object with mechanical energy can do work on another object. In fact, you can think of mechanical energy as the ability to do work. The more mechanical energy an object has, the more work it can do.

Reading Checkpoint **What two forms of energy combine to make mechanical energy?**

FIGURE 5
Mechanical Energy
To find the soccer ball's mechanical energy, add its kinetic energy to its potential energy. Observing *Why does the soccer ball have potential energy?*

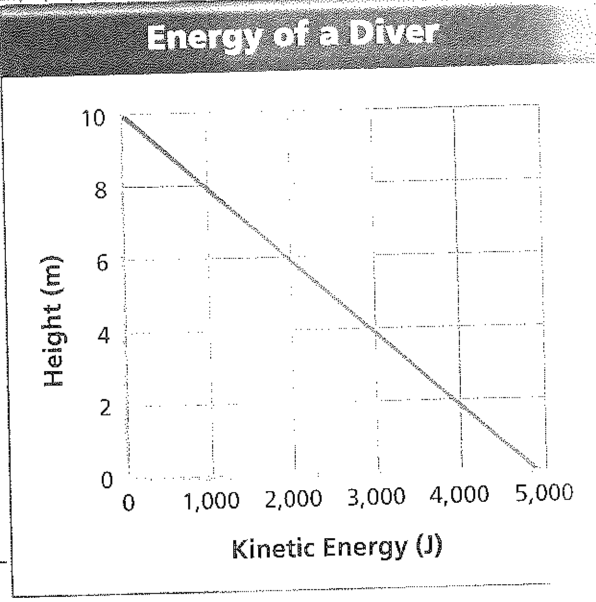


Math Analyzing Data

Calculating Mechanical Energy

The kinetic energy of a 500-N diver during a dive from a 10-m platform was measured. These data are shown in the graph.

1. Reading Graphs According to the graph, how much kinetic energy does the diver have at 8 m?
2. Calculating Using the graph, find the kinetic energy of the diver at 6 m. Then calculate the diver's potential energy at that point.
3. Inferring The mechanical energy of the diver is the same at every height. What is the mechanical energy of the diver?



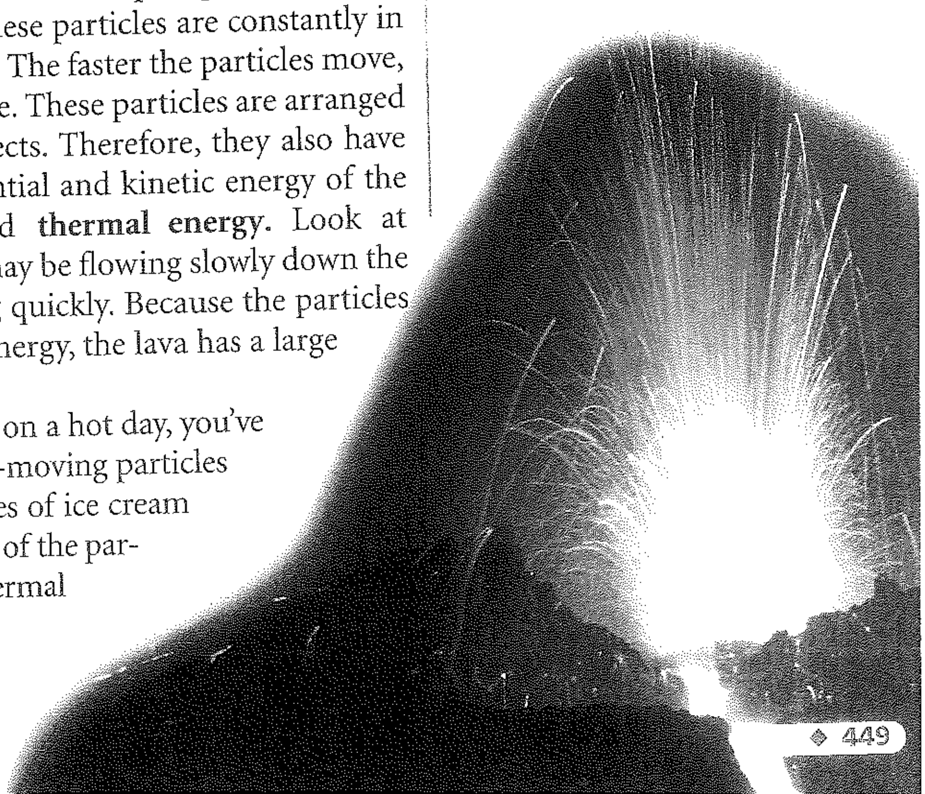
Other Forms of Energy

So far in this chapter, you have read about energy that involves the motion and position of an object. But an object can have other forms of kinetic and potential energy. Most of these other forms are associated with the particles that make up objects. These particles are far too small to see. **Forms of energy associated with the particles of objects include thermal energy, electrical energy, chemical energy, nuclear energy, and electromagnetic energy.**

Thermal Energy All objects are made up of particles called atoms and molecules. Because these particles are constantly in motion, they have kinetic energy. The faster the particles move, the more kinetic energy they have. These particles are arranged in specific ways in different objects. Therefore, they also have potential energy. The total potential and kinetic energy of the particles in an object is called **thermal energy.** Look at Figure 6. Even though the lava may be flowing slowly down the volcano, its particles are moving quickly. Because the particles have a large amount of kinetic energy, the lava has a large amount of thermal energy.

If you've ever eaten ice cream on a hot day, you've experienced thermal energy. Fast-moving particles in the warm air make the particles of ice cream move faster. As the kinetic energy of the particles increases, so does the thermal energy of the ice cream. Eventually, the ice cream melts.

FIGURE 6
Thermal Energy
The lava flowing from this volcano has a large amount of thermal energy. Predicting *Will the thermal energy of the lava increase or decrease as it flows away from the volcano?*



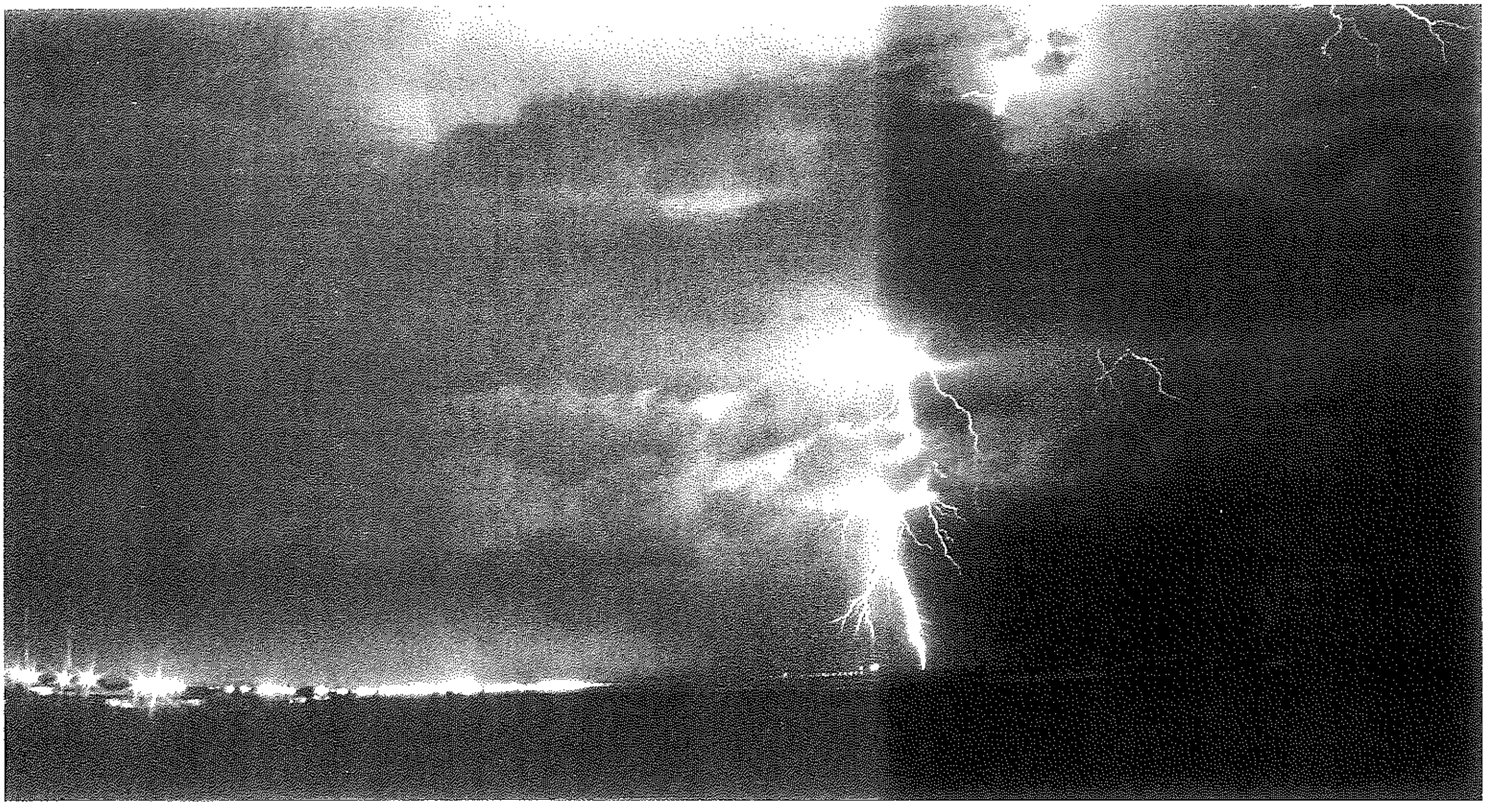


FIGURE 7
Electrical Energy
Electric charges in lightning carry electrical energy.

Electrical Energy When you receive a shock from a metal doorknob, you are experiencing electrical energy. The energy of electric charges is **electrical energy.** Depending on whether the charges are moving or stored, electrical energy can be a form of kinetic or potential energy. The lightning in Figure 7 is a form of electrical energy. You rely on electrical energy from batteries or electrical lines to run devices such as flashlights, handheld games, and radios.

Chemical Energy Almost everything you see, touch, or taste is composed of chemical compounds. Chemical compounds are made up of atoms and molecules. Bonds between the atoms and molecules hold chemical compounds together. These bonds have chemical energy. **Chemical energy** is potential energy stored in the chemical bonds that hold chemical compounds together. Chemical energy is stored in the foods you eat, in the matches you can use to light a candle, and even in the cells of your body. When bonds in chemical compounds break, new chemical compounds may form. When this happens, chemical energy may be released.

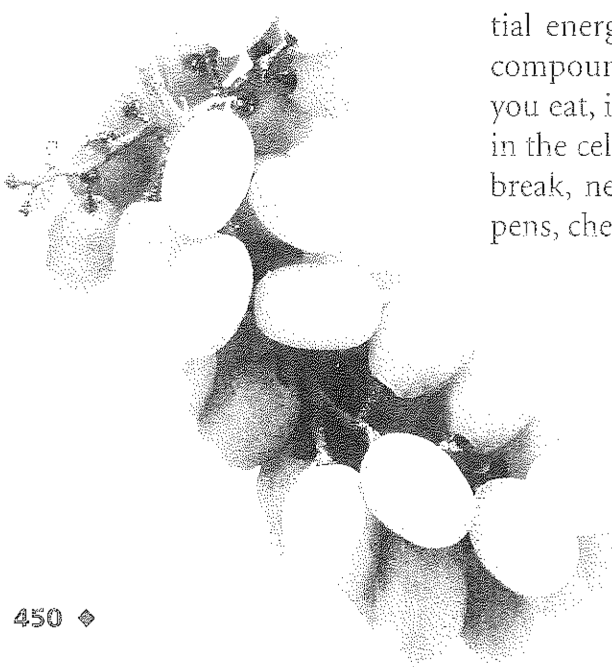


FIGURE 8
Chemical Energy
The particles in these grapes contain chemical energy. Your body can use this energy after you eat them.

Nuclear Energy A type of potential energy called **nuclear energy** is stored in the nucleus of an atom. Nuclear energy is released during a nuclear reaction. One kind of nuclear reaction, known as nuclear fission, occurs when a nucleus splits. Nuclear power plants use fission reactions to produce electricity. Another kind of reaction, known as nuclear fusion, occurs when the nuclei of atoms fuse, or join together. Nuclear fusion reactions occur continuously in the sun, releasing tremendous amounts of energy.

Electromagnetic Energy The sunlight that you see each day is a form of **electromagnetic energy.** Electromagnetic energy travels in waves. These waves have some electrical properties and some magnetic properties.

The microwaves you use to cook your food and the X-rays doctors use to examine patients are types of electromagnetic energy. Other forms of electromagnetic energy include ultraviolet radiation, infrared radiation, and radio waves.

Reading Checkpoint **What form of energy are microwaves?**

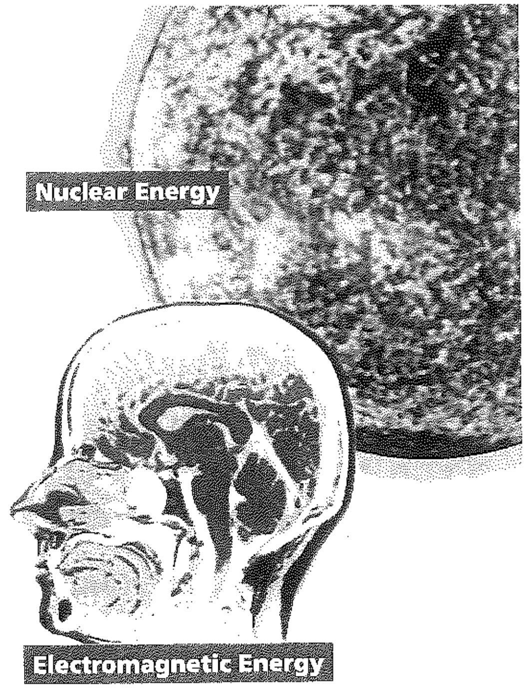


FIGURE 9
Nuclear and Electromagnetic Energy
The sun is a source of nuclear energy. Doctors use X-rays, a form of electromagnetic energy, when taking a CT scan to look for brain disorders. Observing *What other forms of energy from the sun can you observe?*

Section 2 Assessment

Target Reading Skill Building Vocabulary Use your definitions to help answer the questions.

Reviewing Key Concepts

1. a. Defining What is mechanical energy?
   b. Drawing Conclusions If an object's mechanical energy is equal to its potential energy, how much kinetic energy does the object have? How do you know?
   c. Calculating If the kinetic energy of a falling apple is 5.2 J and its potential energy is 3.5 J, what is its mechanical energy?
2. a. Listing List the five forms of energy associated with the particles that make up objects.
   b. Explaining Why do the particles of objects have both kinetic and potential energy?
   c. Classifying What kind of energy do you experience when you eat a peanut butter and jelly sandwich?

Writing in Science

Detailed Observation In terms of energy, think about what happens when you eat a hot meal. Describe all the different forms of energy that you experience. For example, if you are eating under a lamp, its electromagnetic energy helps you see the food. Explain the source of each form of energy.

Lab zone **Skills Lab**

Can You Feel the Power?

Problem

Can you change your power while exercising?

Skills Focus

calculating, interpreting data

Materials

- calculator
- meter stick
- stopwatch or clock with a second hand
- board, about 2.5 cm × 30 cm × 120 cm
- 18–20 books, each about 2 cm thick

Procedure

1. Construct a step by making two identical stacks of books. Each stack should be about 20 cm high. Place a board securely on top of the stacks of books so that the ends of the board are even with the outside edges of the books. **CAUTION:** *Be sure to have your partners hold the board steady and level throughout the procedure.*
2. Copy the data table into your notebook.
3. You gain gravitational potential energy every time you step up. Gaining energy requires work.

   Work = Weight × Height = Gravitational potential energy

   a. Assume your weight is 400 N and your partners' weights are 425 N and 450 N.

   b. Measure the vertical distance in centimeters from the floor to the top of the board. Convert to meters by dividing by 100 and record this height in the data table.
4. Calculate the work you do in stepping up onto the board once. Then calculate the work you do stepping up onto the board 20 times. Record both answers in your data table.
5. Step up onto the board with both feet and then step backwards off the board onto the floor. This up and down motion is one repetition. Make sure you are comfortable with the motion.
6. Have one partner time how long it takes you to do 20 repetitions performed at a constant speed. Count out loud to help the timer keep track of the number of repetitions. Record the time in your data table.
7. Calculate the power over 20 repetitions. (Power = Energy transferred ÷ Time.) Predict how your results will change if you step up and down at different speeds.
8. Repeat Steps 6 and 7, but climb the step more slowly than you did the first time. Record the new data in the Trial 2 row of your data table.
9. Switch roles with your partners and repeat Steps 3 through 8 with a different weight from Step 3(a).

Data Table

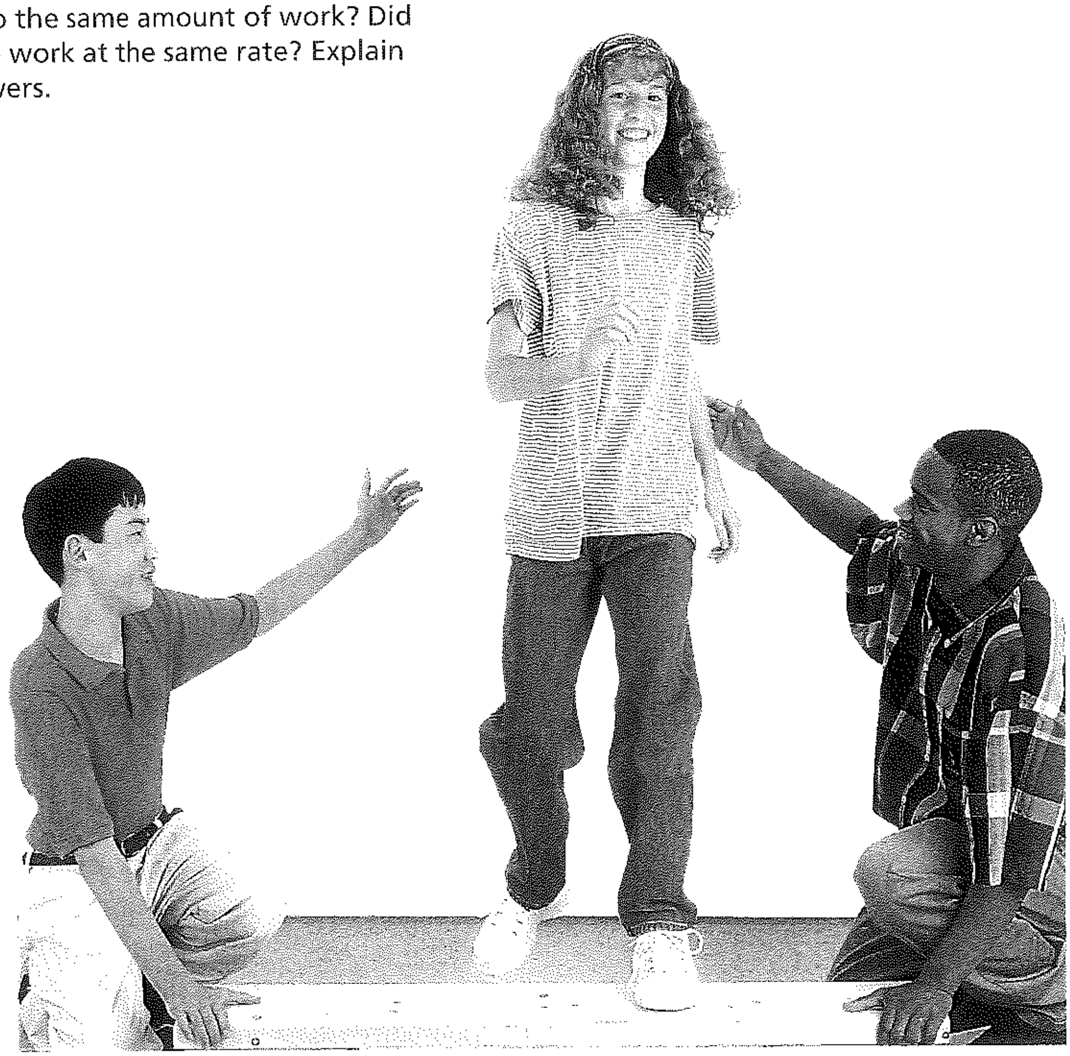
Trial	Weight (N)	Height of Board (m)	Time for 20 Repetitions (s)	Work for 1 Repetition (J)	Work for 20 Repetitions (J)	Power (W)
Student 1, Trial 1						
Student 1, Trial 2						

Analyze and Conclude

1. Calculating What is the gravitational potential energy gained from stepping up onto the board? How does this compare to the amount of work required to step up onto the board?
2. Interpreting Data Compare the amount of work you did during your first and second trials.
3. Interpreting Data Compare the power during your first and second trials.
4. Drawing Conclusions Did you and your partners all do the same amount of work? Did you all do work at the same rate? Explain your answers.
5. Communicating Often, a physical therapist will want to increase a patient's power. Write a letter to a physical therapist suggesting how he or she could use music to change a patient's power.

Design an Experiment

Design an experiment to test two other ways a physical therapist could change the power output of her patients. *Obtain your teacher's permission before carrying out your investigation.*



Section 3

Energy Transformations and Conservation

Reading Preview

Key Concepts

- How are different forms of energy related?
- What is a common energy transformation?
- What is the law of conservation of energy?

Key Terms

- energy transformation
- law of conservation of energy
- matter

Target Reading Skill

Asking Questions Before you read, preview the red headings and ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

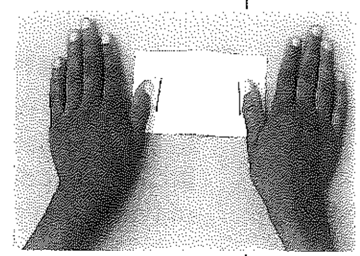
Energy Transformations

Question	Answer
What is an energy transformation?	An energy transformation is . . .

▼ Niagara Falls is more than 50 meters high.

Lab zone Discover Activity

What Would Make a Card Jump?



1. Fold an index card in half.
2. In the edge opposite the fold, cut two slits that are about 2 cm long and 2 cm apart.
3. Keep the card folded and loop a rubber band through the slits. With the fold toward you, gently open the card like a tent and flatten it against your desk.
4. Predict what will happen to the card if you let go. Then test your prediction.

Think It Over

Drawing Conclusions Describe what happened to the card. Based on your observations, what is the relationship between potential and kinetic energy?

The spray bounces off your raincoat as you look up at the millions of liters of water plunging toward you. The roar of the water is deafening. Are you doomed? Fortunately not—you are on a sightseeing boat at the foot of the mighty Niagara Falls. The waterfall carries the huge amount of water that drains from the upper Great Lakes. It lies on the border between Canada and the United States.

What many visitors don't know, however, is that Niagara Falls serves as much more than just a spectacular view. The Niagara Falls area is the center of a network of electrical power lines. Water that is diverted above the falls is used to generate electricity for much of the surrounding region.

Energy Transformations

What does flowing water have to do with electricity? You may already know that the mechanical energy of moving water can be transformed into electrical energy. **Most forms of energy can be transformed into other forms.** A change from one form of energy to another is called an **energy transformation.** Some energy changes involve single transformations, while others involve many transformations.

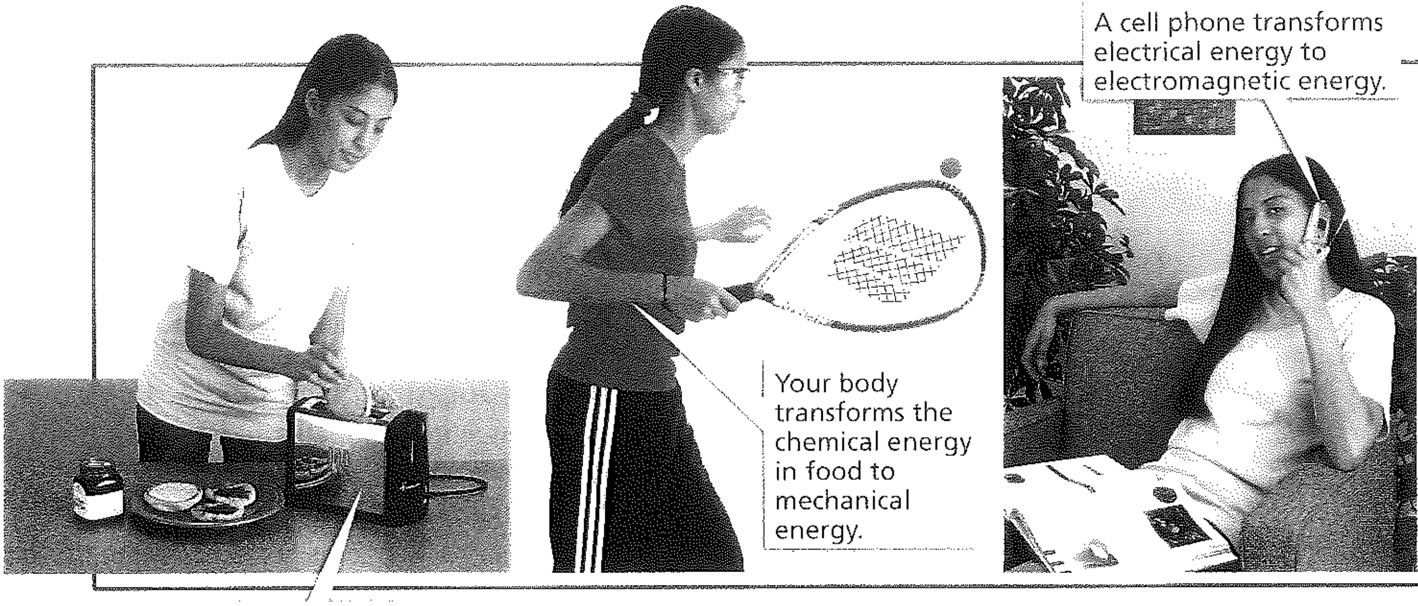


FIGURE 10
Common Energy Transformations
Every day, energy transformations are all around you. Some of these transformations happen inside you! Observing *What other energy transformations do you observe every day?*

Single Transformations Sometimes, one form of energy needs to be transformed into another to get work done. You are already familiar with many such energy transformations. For example, a toaster transforms electrical energy to thermal energy to toast your bread. A cell phone transforms electrical energy to electromagnetic energy that travels to other phones.

Your body transforms the chemical energy in your food to mechanical energy you need to move your muscles. Chemical energy in food is also transformed to the thermal energy your body uses to maintain its temperature.

Multiple Transformations Often, a series of energy transformations is needed to do work. For example, the mechanical energy used to strike a match is transformed first to thermal energy. The thermal energy causes the particles in the match to release stored chemical energy, which is transformed to thermal energy and the electromagnetic energy you see as light.

In a car engine, another series of energy conversions occurs. Electrical energy produces a spark. The thermal energy of the spark releases chemical energy in the fuel. The fuel's chemical energy in turn becomes thermal energy. Thermal energy is converted to mechanical energy used to move the car, and to electrical energy to produce more sparks.

Reading Checkpoint **What is an example of a multiple transformation of energy?**

Lab zone **Skills Activity**

Classifying

Many common devices transform electrical energy into other forms. Think about the following devices in terms of energy transformations.

- steam iron
- ceiling fan
- digital clock
- dryer

For each device, describe which form or forms of energy the electrical energy becomes. Do these devices produce single or multiple transformations of energy?

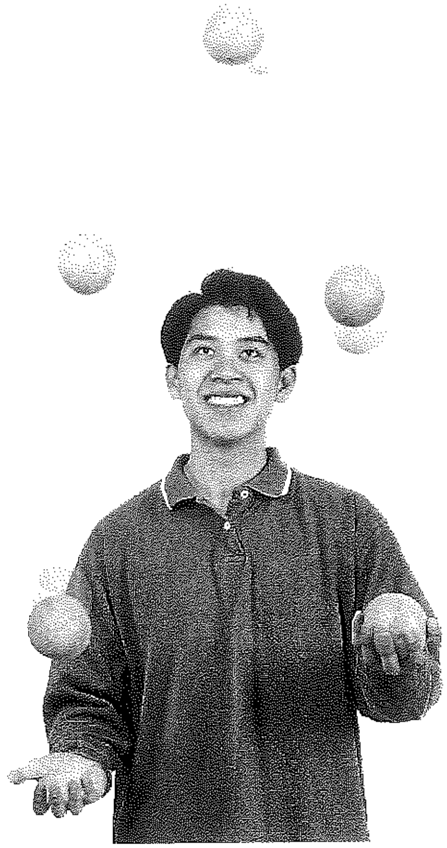


FIGURE 11
Juggling The kinetic energy of an orange thrown into the air becomes gravitational potential energy. Its potential energy becomes kinetic energy as it falls.

Transformations Between Potential and Kinetic Energy

One of the most common energy transformations is the transformation between potential energy and kinetic energy. In waterfalls such as Niagara Falls, potential energy is transformed to kinetic energy. The water at the top of the falls has gravitational potential energy. As the water plunges, its velocity increases. Its potential energy becomes kinetic energy.

Energy Transformation in Juggling Any object that rises or falls experiences a change in its kinetic and gravitational potential energy. Look at the orange in Figure 11. When it moves, the orange has kinetic energy. As it rises, it slows down. Its potential energy increases as its kinetic energy decreases. At the highest point in its path, it stops moving. Since there is no motion, the orange no longer has kinetic energy. But it does have potential energy. As the orange falls, the energy transformation is reversed. Kinetic energy increases while potential energy decreases.

Energy Transformation in a Pendulum In a pendulum, a continuous transformation between kinetic and potential energy takes place. At the highest point in its swing, the pendulum in Figure 12 has no movement, so it only has gravitational potential energy. As it swings downward, it speeds up. Its potential energy is transformed to kinetic energy. The pendulum is at its greatest speed at the bottom of its swing. There, all its energy is kinetic energy.

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Visit: PHSchool.com
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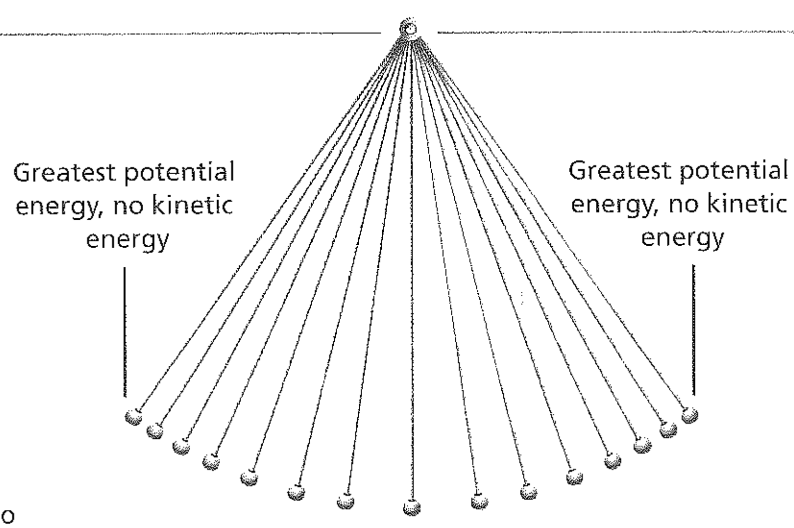


FIGURE 12
Pendulum
A pendulum continuously transforms energy from kinetic to potential energy and back.
Interpreting Diagrams *At what two points is the pendulum's potential energy greatest?*

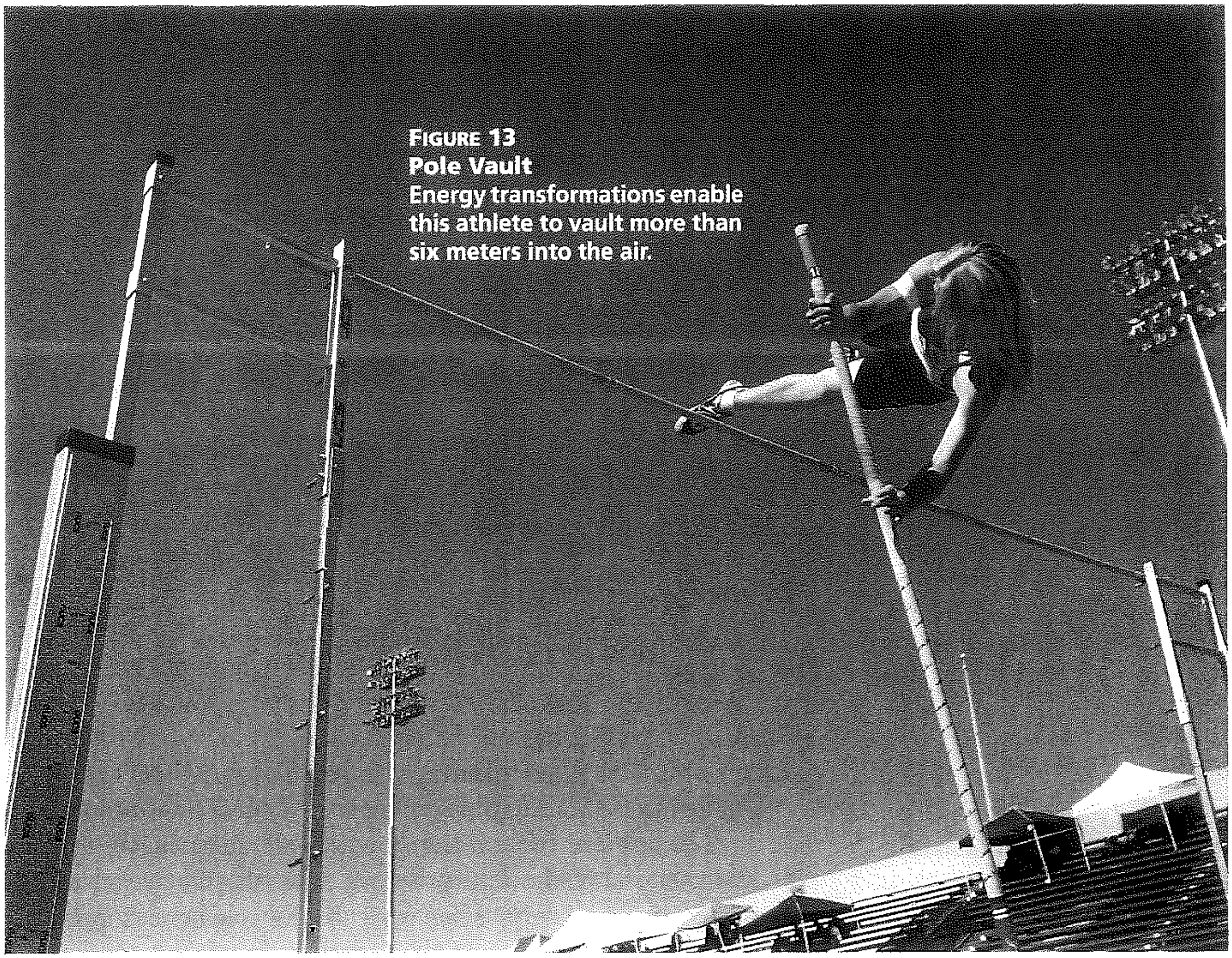


FIGURE 13
Pole Vault
Energy transformations enable this athlete to vault more than six meters into the air.

As the pendulum swings to the other side, its height increases. The pendulum regains gravitational potential energy and loses kinetic energy. At the top of its swing, it comes to a stop again. And so the pattern of energy transformation continues.

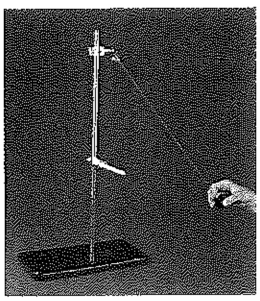
Energy Transformation in a Pole Vault A pole-vaulter transforms kinetic energy to elastic potential energy, which then becomes gravitational potential energy. The pole-vaulter you see in Figure 13 has kinetic energy as he runs forward. When the pole-vaulter plants the pole to jump, his velocity decreases and the pole bends. His kinetic energy is transformed to elastic potential energy in the pole. As the pole straightens out, the pole-vaulter is lifted high into the air. The elastic potential energy of the pole is transformed to the gravitational potential energy of the pole-vaulter. Once he is over the bar, the pole-vaulter's gravitational potential energy is transformed back into kinetic energy as he falls toward the safety cushion.

Reading Checkpoint **What kind of energy lifts a pole-vaulter over the bar?**

Lab zone **Try This Activity**

Pendulum Swing

1. Set up a pendulum using washers or a rubber stopper, string, a ring stand, and a clamp.
2. Pull the pendulum back so that it makes a 45° angle with the vertical. Measure the height of the stopper. Release it and observe how high it swings.



3. Use a second clamp to reduce the length of the pendulum as shown. The pendulum will run into the second clamp at the bottom of its swing.
4. Pull the pendulum back to the same height as you did the first time. Predict how high the pendulum will swing. Then set it in motion and observe.

Observing How high did the pendulum swing in each case? Explain your observations.

Conservation of Energy

If you set a spinning top in motion, will the top remain in motion forever? No, it will not. Then what happens to its energy? Is the energy destroyed? Again, the answer is no. The **law of conservation of energy** states that when one form of energy is transformed to another, no energy is destroyed in the process. **According to the law of conservation of energy, energy cannot be created or destroyed.** So the total amount of energy is the same before and after any transformation. If you add up all the new forms of energy after a transformation, all of the original energy will be accounted for.

Energy and Friction So what happens to the energy of the top in Figure 14? As the top spins, it encounters friction with the floor and friction from the air. Whenever a moving object experiences friction, some of its kinetic energy is transformed into thermal energy. So, the mechanical energy of the spinning top is transformed to thermal energy. The top slows and eventually falls on its side, but its energy is not destroyed—it is transformed.

The fact that friction transforms mechanical energy to thermal energy should not surprise you. After all, you take advantage of such thermal energy when you rub your cold hands together to warm them up. The fact that friction transforms mechanical energy to thermal energy explains why no machine is 100 percent efficient. You may recall that the output work of any real machine is always less than the input work. This reduced efficiency occurs because some mechanical energy is always transformed into thermal energy due to friction.

FIGURE 14
Conservation of Energy
A spinning top's kinetic energy is not lost. It is transformed into thermal energy through friction.
Applying Concepts *How much of the top's kinetic energy becomes thermal energy?*

Energy and Matter You might have heard of Albert Einstein's theory of relativity. His theory stated that energy *can* sometimes be created—by destroying matter! **Matter** is anything that has mass and takes up space. All objects are made up of matter.

Just as one form of energy can be transformed to other forms, Einstein discovered that matter can be transformed to energy. In fact, destroying just a small amount of matter releases a huge amount of energy.

Einstein's discovery meant that the law of conservation of energy had to be adjusted. In some situations, energy alone is not conserved. However, since matter can be transformed to energy, scientists say matter and energy together are always conserved.

Reading Checkpoint How can energy be created?

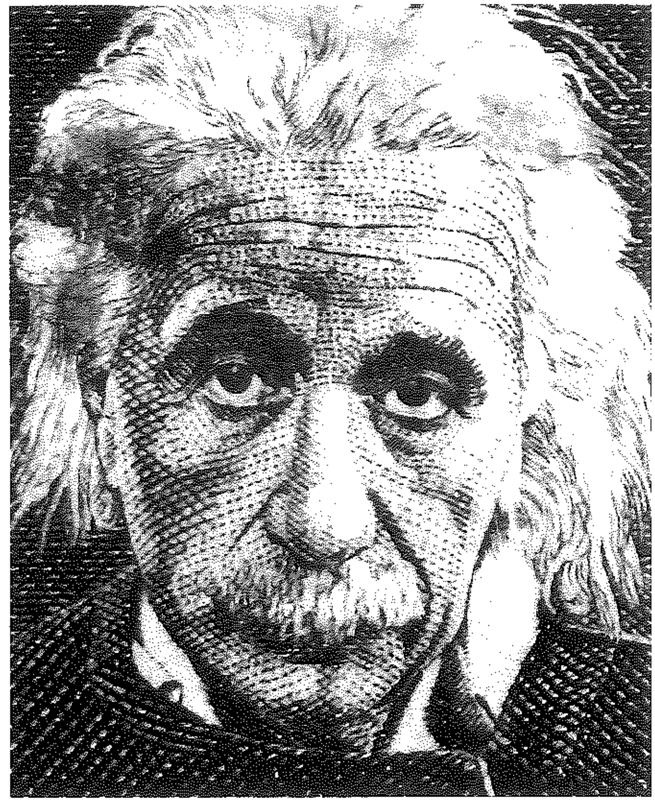


FIGURE 15
Albert Einstein
Einstein published his theory of special relativity in 1905.

Section 3 Assessment

Target Reading Skill Asking Questions Use the answers to the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. a. Reviewing What is the relationship between different forms of energy?
   b. Relating Cause and Effect When you turn a toaster on, what happens to the electrical energy?
   c. Sequencing Describe the energy transformations that happen when you strike a match. List them in the order in which they occur.
2. a. Identifying What common energy transformation allows you to send a rubber band flying across the room?
   b. Describing Describe the energy transformations that occur when you bounce a ball.
   c. Interpreting Diagrams Describe the energy transformations that occur in the pendulum in Figure 12.
3. a. Summarizing State the law of conservation of energy in your own words.
   b. Explaining Thermal energy is produced when a firefighter slides down a pole. Where does it come from?
   c. Making Generalizations Based on the theory of relativity, what must always be conserved?

Lab zone At-Home Activity

Hot Wire Straighten a wire hanger. Have a family member feel the wire and observe whether it feels cool or warm. Then hold the ends of the wire and bend it back and forth several times. **CAUTION:** *If the wire breaks, it can be sharp.* Do not bend it more than a few times. After bending the wire, have your family member feel it again. Explain how energy transformations can produce a change in temperature.

Lab zone **Skills Lab**

Soaring Straws

Problem

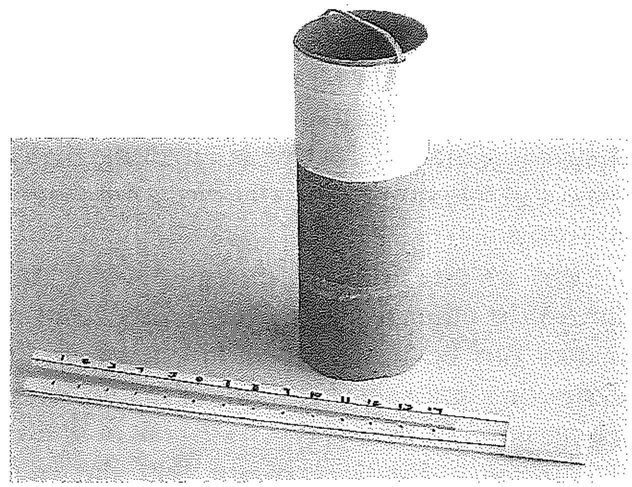
How does the gravitational potential energy of a straw rocket depend on the elastic potential energy of a rubber band launcher?

Skills Focus

controlling variables, graphing

Materials

- scissors
- rubber band
- 3 plastic straws
- meter stick
- marker
- metric ruler
- balance
- masking tape
- empty toilet paper tube



Making A Rocket and Launcher

A Cut a rubber band and tape it across the open end of a hollow cylinder, such as a toilet paper tube. The rubber band should be taut, but stretched only a tiny amount. This is the launcher.

B Cut about 3 cm off a plastic straw.

C Lay 2 full-length straws side by side on a flat surface with the 3-cm piece of straw between them. Arrange the straws so that their ends are even.

D Tape the straws together side by side. Starting from the untaped end, make marks every centimeter on one of the long straws. This is the rocket.

Procedure

1. Construct the rocket and launcher following the instructions in the box above. Use a balance to find the mass of the rocket in grams. Record the mass.
2. Hold the launcher in one hand with your fingers over the ends of the rubber band. Load the launcher by placing the straw rocket on the rubber band and pulling down from the other end as shown in the photograph. Let go and launch the rocket straight up. **CAUTION:** *Be sure to aim the straw rocket into the air, not at classmates.*
3. In your notebook, make a data table similar to the one on the next page.
4. Have your partner hold a meter stick, or tape it to the wall, so that its zero end is even with the top of the rocket launcher. Measure the height, in meters, to which the rocket rises. If the rocket goes higher than a single meter stick, use two meter sticks.
5. You can measure the amount of stretch of the rubber band by noting where the markings on the rocket line up with the bottom of the launching cylinder. Launch the rocket using five different amounts of stretch. Record your measurements.
6. For each amount of stretch, find the average height to which the rocket rises. Record the height in your data table.
7. Find the gravitational potential energy for each amount of stretch:

   Gravitational potential energy = Mass × Gravitational acceleration × Height

   You have measured the mass in grams. So the unit of energy is the millijoule (mJ), which is one thousandth of a joule. Record the results in your data table.

Data Table					
Amount of Stretch (cm)	Height Trial 1 (m)	Height Trial 2 (m)	Height Trial 3 (m)	Average Height (m)	Gravitational Potential Energy (mJ)

Analyze and Conclude

1. Controlling Variables Which variable in your data table is the manipulated variable? The responding variable? How do you know?
2. Graphing Graph your results. Show gravitational potential energy on the vertical axis and amount of stretch on the horizontal axis.
3. Measuring In this experiment, what measurement is related to elastic potential energy?
4. Drawing Conclusions Look at the shape of the graph. What conclusions can you reach about the relationship between the gravitational potential energy of the rocket and the elastic potential energy of the rubber band?
5. Inferring When you release the rocket, what kind of energy does the rocket have just after takeoff? What are the elastic potential energy and the gravitational potential energy at this point?
6. Developing Hypotheses Make an additional column on the right side of your data table labeled Kinetic Energy (mJ). For each row, write down what you think the rocket's kinetic energy is right after takeoff.
7. Communicating Write an advertisement for your rocket launcher. Include a diagram explaining how the rocket gains potential energy, how its potential energy is transformed to kinetic energy, and how its kinetic energy is transformed back into potential energy.

Design an Experiment

How would the height and distance the rocket travels be affected by the angle of launch? Design an experiment to measure the height and distance resulting from different launch angles. Keep the amount of stretch constant. *Obtain your teacher's permission before carrying out your investigation.*

Energy and Fossil Fuels

Reading Preview

Key Concepts

- What is the source of the energy stored in fossil fuels?
- How is energy transformed when fossil fuels are used?

Key Terms

- fossil fuel
- combustion

Target Reading Skill

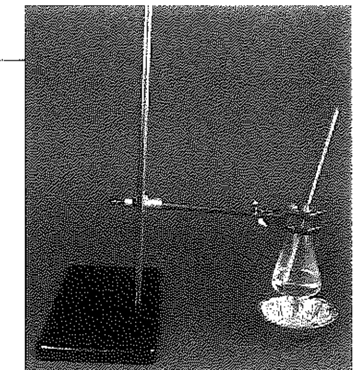
Previewing Visuals When you preview, you look ahead at the material to be read. Preview Figure 18. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

Using Fossil Fuel Energy

Q. What energy transformation occurs in the sun?
A.
Q.

Lab zone Discover Activity

What Is a Fuel?



1. Put on your goggles. Attach a flask to a ring stand with a clamp. Then place a thermometer in the flask.
2. Add enough water to the flask to cover the thermometer bulb. Record the temperature of the water. Remove the thermometer.
3. Fold a wooden coffee stirrer in three places to look like a W. Stand it in a small aluminum pan so that the W is upright. Position the pan 4–5 cm directly below the flask.
4. Ignite the coffee stirrer at its center. **CAUTION:** *Be careful when using matches.*
5. When the coffee stirrer has stopped burning, read the temperature of the water again. Allow the flask to cool before cleaning up.

Think It Over

Forming Operational Definitions Gasoline in a car, kerosene in a lantern, and a piece of wood are all fuels. Based on your observations, what is a fuel?

Imagine a lush, green, swampy forest. Ferns as tall as trees block the view. Enormous dragonflies buzz through the warm, moist air. Huge cockroaches, some longer than your finger, crawl across the ground. Where is this place? Actually, a better question to ask would be, *when* is it? The time is more than 400 million years ago. That's even before the dinosaurs lived! But what does this ancient forest have to do with you?

Formation of Fossil Fuels

The plants of vast forests that once covered Earth provide the energy stored in fuels. A fuel is a material that contains stored potential energy. The gasoline used in vehicles and the propane used in a gas grill are examples of fuels. Some of the fuels used today were made from materials that formed hundreds of millions of years ago. These fuels, which include coal, petroleum, and natural gas, are known as **fossil fuels.**

Go Online
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The vast, ancient forests were the source of coal. When plants and animals died, their remains piled up in thick layers in swamps and marshes. Clay and sand sediments covered their remains. The resulting pressure and high temperature turned the remains into coal.

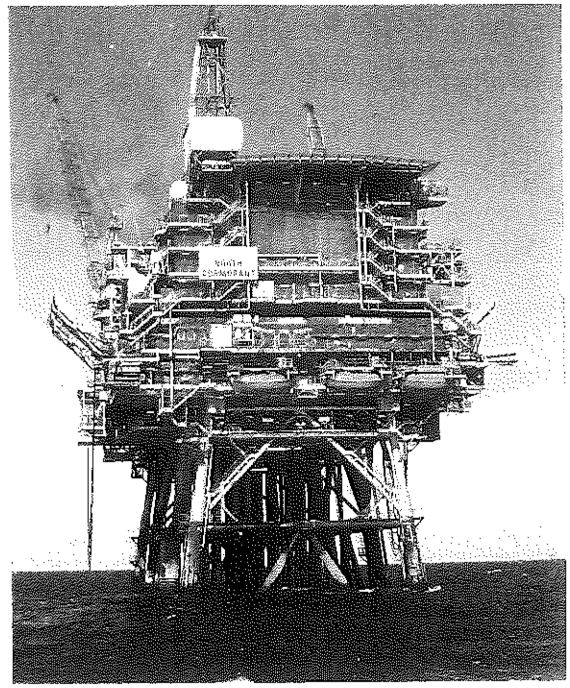


FIGURE 16
Fossil Fuels
Offshore oil rigs drill for the fossil fuel petroleum under the ocean floor.

Energy From the Sun Remember that energy is conserved. That means that fuels do not create energy. So if fossil fuels store energy, they must have gotten energy from somewhere else. But where did it come from? **Fossil fuels contain energy that came from the sun.** In fact, the sun is the source of energy for most of Earth's processes. Within the dense core of the sun, during the process of nuclear fusion, nuclear energy is transformed to electromagnetic energy as well as other forms. Some of this electromagnetic energy reaches Earth in the form of light.

Reading Checkpoint **What is the source of the energy stored in fossil fuels?**

FIGURE 17
Mining for Coal
Miners use heavy machinery to dig for coal. **Developing Hypotheses** *Why is coal usually found underground?*

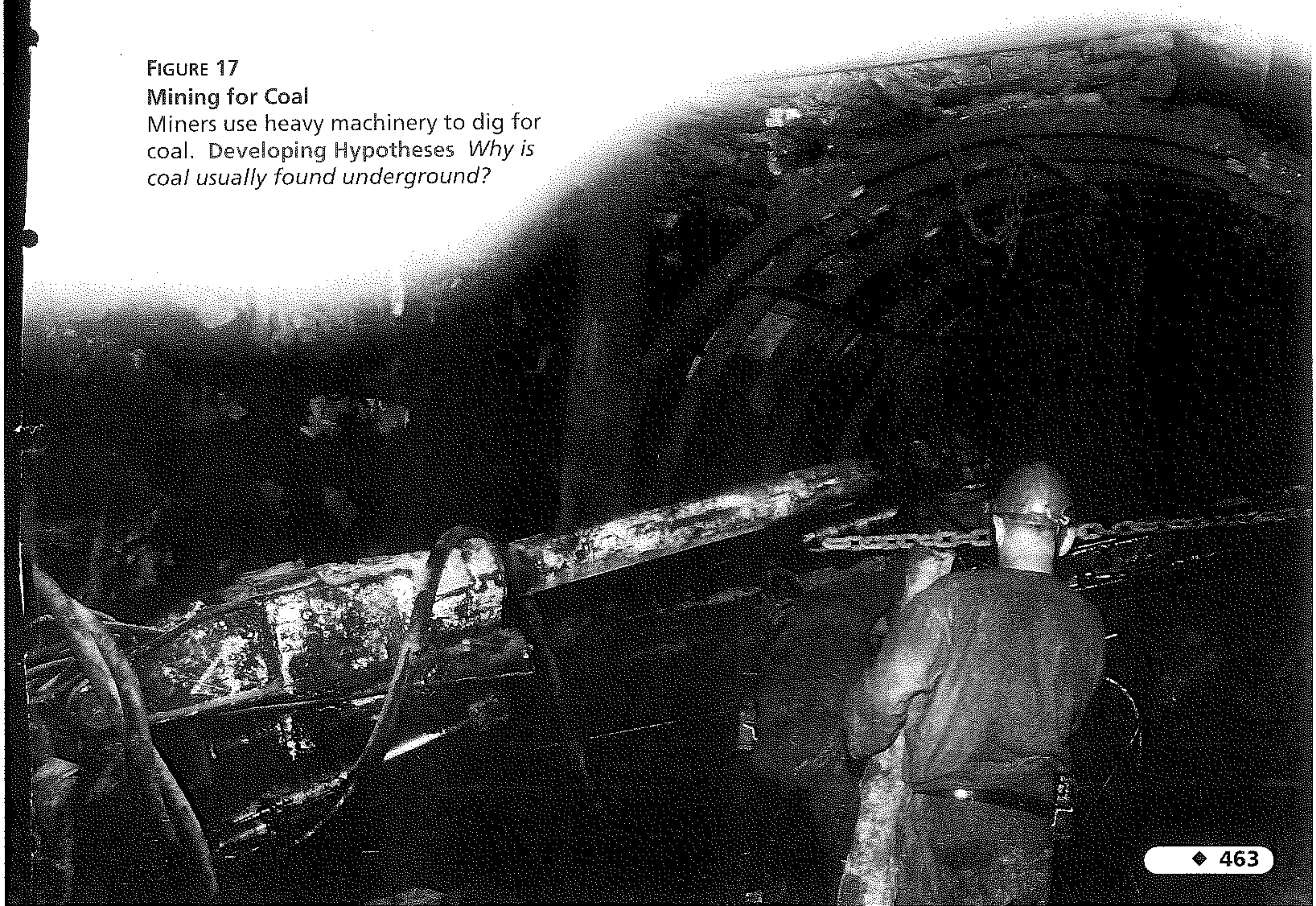
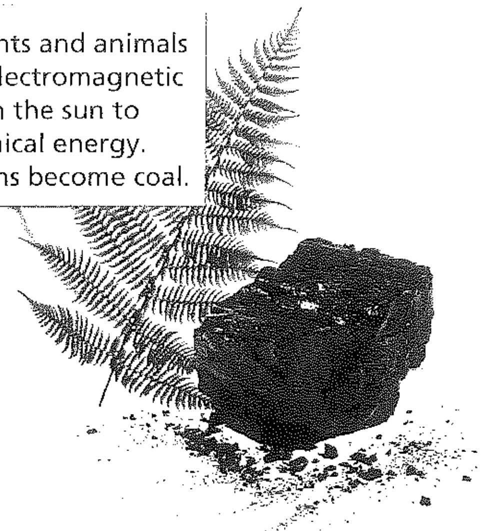


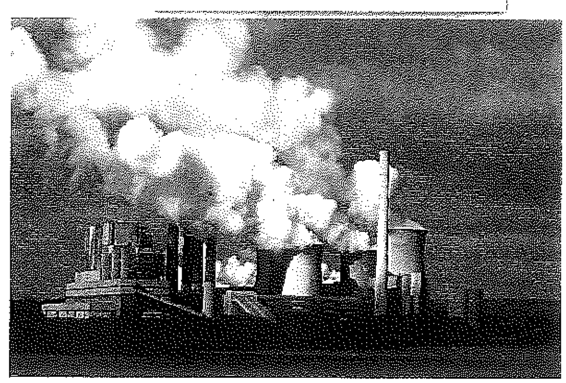
FIGURE 18
Using Fossil Fuel Energy
The chemical energy in fossil fuels comes from the sun. Millions of years later, power plants transform that chemical energy to the electrical energy that powers your hair dryer.
Interpreting Diagrams *What does a turbine do?*

1. The sun transforms nuclear energy to electromagnetic energy.

2. Ancient plants and animals transform electromagnetic energy from the sun to stored chemical energy. Their remains become coal.



3. Coal is burned to make steam, transforming stored chemical energy to thermal energy.



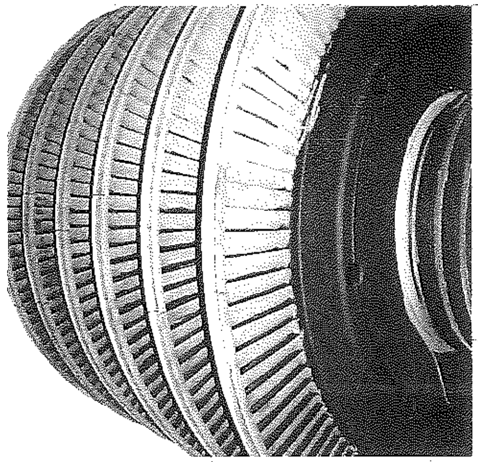
Lab zone Skills Activity

Graphing
The following list shows what percent of power used in the United States in a recent year came from each energy source: coal, 23%; nuclear, 8%; oil, 39%; natural gas, 24%; water, 3%; and biofuels, 3%. Prepare a circle graph that presents these data. (See the Skills Handbook for more on circle graphs.)

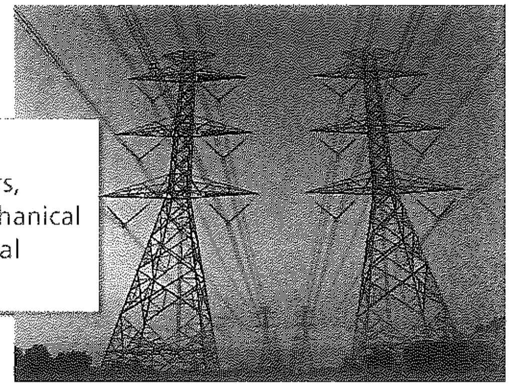
What power source does the United States rely on most? What percent of the country's total energy needs is met by coal, oil, and natural gas combined?

The Sun's Energy on Earth When the sun's energy reaches Earth, certain living things—plants, algae, and certain bacteria—transform some of it to chemical energy. Some of the energy in the chemical compounds they make is used for their daily energy needs. The rest is stored. Animals that eat plants store some of the plant's chemical energy in their own cells. When ancient animals and plants died, the chemical energy they had stored was trapped within them. This trapped energy is the chemical energy found in coal.

Use of Fossil Fuels
Fossil fuels can be burned to release the chemical energy stored millions of years ago. The process of burning fuels is known as **combustion.** During combustion, the fuel's chemical energy is transformed to thermal energy. This thermal energy can be used to heat water until the water boils and produces steam. In modern, coal-fired power plants, the steam is raised to a very high temperature in a boiler. When it leaves the boiler it has enough pressure to turn a turbine.



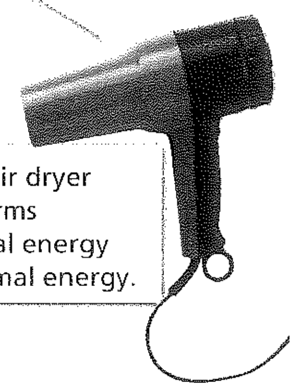
4 The steam turns turbines, transforming thermal energy to mechanical energy.



5 The turbines spin electric generators, transforming mechanical energy to electrical energy.

A turbine is like a fan, with blades attached to an axle. The pressure of the steam on the blades causes the turbine to spin very fast. In this process, the thermal energy of the steam is transformed to the mechanical energy of the moving turbine.

The turbines are connected to generators. When turbines spin them, generators produce electricity. As you can see in Figure 18, a power plant transforms chemical energy to thermal energy to mechanical energy to electrical energy. This electrical energy is then used to light your home and run other devices, such as a hair dryer.



6 Your hair dryer transforms electrical energy to thermal energy.

Reading Checkpoint **What energy transformations take place in a power plant?**

Section 4 Assessment

Target Reading Skill Previewing Visuals Refer to your questions and answers about Figure 18 to help you answer Question 2 below.

Reviewing Key Concepts

1. a. Defining What are fossil fuels?
   b. Explaining What role did the sun play in making fossil fuels?
   c. Drawing Conclusions How did ancient animals receive stored energy from the sun?
2. a. Reviewing How is the chemical energy stored in coal released?
   b. Sequencing Describe the steps in which a power plant transforms the energy in fossil fuels to electrical energy.
   c. Inferring Which steps in the power plant process rely on potential energy? Which steps rely on kinetic energy? Why?

Lab zone At-Home Activity

Burning Fossils Some appliances in your home, such as ovens, grills, and water heaters, may use fossil fuels as an energy source. With a family member, search your home for appliances that use fossil fuels such as petroleum, coal, or natural gas as a source of energy. Explain to your family member what fossil fuels are and how they form.

Chapter 13 Study Guide

The BIG Idea **Energy Forms and Conservation** Energy is the ability to do work or cause change. Energy can be transformed from one form into another, but it cannot be created or destroyed.

1 What Is Energy?

Key Concepts

- If the transfer of energy is work, then power is the rate at which energy is transferred, or the amount of energy transferred in a unit of time.
- $\text{Power} = \frac{\text{Energy transferred}}{\text{Time}}$
- Two basic kinds of energy are kinetic energy and potential energy.
- $\text{Kinetic energy} = \frac{1}{2} \times \text{Mass} \times \text{Velocity}^2$
- $\text{Gravitational potential energy} = \text{Weight} \times \text{Height}$

Key Terms

energy
kinetic energy
potential energy
gravitational potential energy
elastic potential energy

2 Forms of Energy

Key Concepts

- You can find an object's mechanical energy by adding the object's kinetic energy and potential energy.

  $\text{Mechanical energy} = \text{Kinetic energy} + \text{Potential energy}$
- Forms of energy associated with the particles of objects include thermal energy, electrical energy, chemical energy, nuclear energy, and electromagnetic energy.

Key Terms

mechanical energy
thermal energy
electrical energy
chemical energy
nuclear energy
electromagnetic energy

3 Energy Transformations and Conservation

Key Concepts

- Most forms of energy can be transformed into other forms.
- One of the most common energy transformations is the transformation between potential energy and kinetic energy.
- According to the law of conservation of energy, energy cannot be created or destroyed.

Key Terms

energy transformation
law of conservation of energy
matter

4 Energy and Fossil Fuels

Key Concepts

- Fossil fuels contain energy that came from the sun.
- Fossil fuels can be burned to release the chemical energy stored millions of years ago.

Key Terms

fossil fuel
combustion

Review and Assessment

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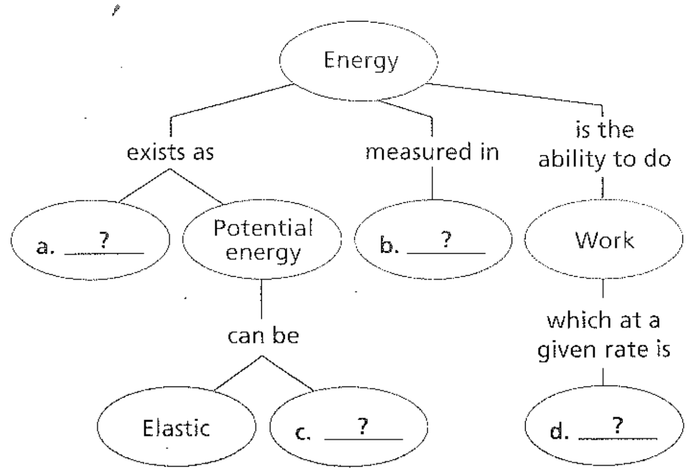
Organizing Information

Concept Mapping Copy the concept map about energy onto a separate sheet of paper. Then complete it and add a title. (For more on Concept Mapping, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. Energy of motion is called
   a. kinetic energy.
   b. elastic potential energy.
   c. gravitational potential energy.
   d. chemical energy.
2. When you stretch a rubber band, you give it
   a. kinetic energy.
   b. elastic potential energy.
   c. gravitational potential energy.
   d. electrical energy.
3. The energy associated with the position and motion of an object is called
   a. potential energy.
   b. nuclear energy.
   c. mechanical energy.
   d. thermal energy.
4. The energy stored in the nucleus of an atom is called
   a. electromagnetic energy.
   b. electrical energy.
   c. chemical energy.
   d. nuclear energy.
5. Fossil fuels store energy from the sun as
   a. chemical energy.
   b. thermal energy.
   c. electromagnetic energy.
   d. electrical energy.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. Kinetic energy is related to an object's height.
7. Electrical energy is the total kinetic and potential energy of the particles in an object.
8. The law of conservation of energy states that when one form of energy is transformed to another, no energy is destroyed.
9. Energy is anything that has mass and takes up space.
10. Combustion is the process of burning fuels.

Writing in Science

Interview You are preparing to interview an Olympic skier for a children's science magazine. Prepare a list of questions that you would ask the skier about the energy transformations that occur while skiing.

Review and Assessment

Checking Concepts

11. Define work in terms of energy.

12. How do you find an object's mechanical energy?

13. For each of the following, decide which forms of energy are present: a walnut falls from a tree; a candle burns; a spring is stretched.

14. An eagle flies from its perch in a tree to the ground to capture and eat its prey. Describe its energy transformations.

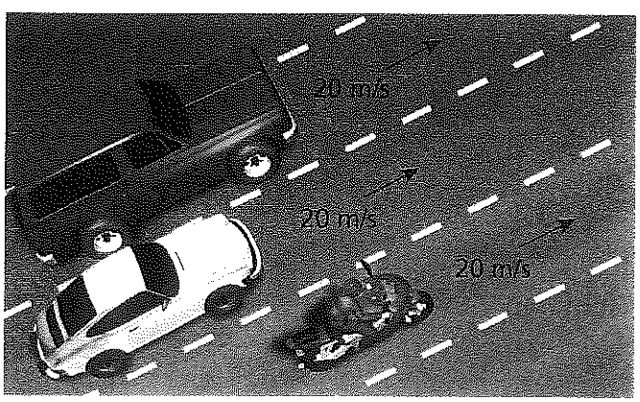
15. How does energy become stored in a fossil fuel? What kind of energy is stored?

Thinking Critically

16. Calculating Find the power of a machine that transfers 450 J of energy in 9 s.

17. Calculating A 1,350-kg car travels at 12 m/s. What is its kinetic energy?

18. Comparing and Contrasting In the illustration below, which vehicle has the least kinetic energy? The greatest kinetic energy? Explain your answers.



19. Problem Solving A 380-N girl walks down a flight of stairs so that she is 2.5 m below her starting level. What is the change in the girl's gravitational potential energy?

20. Applying Concepts One chef places a pie in the oven at a low setting so that it is baked in one hour. Another chef places a pie in the oven at a high setting so that the pie bakes in 30 minutes. Is the amount of energy the same in each case? Is the power the same?

Math Practice

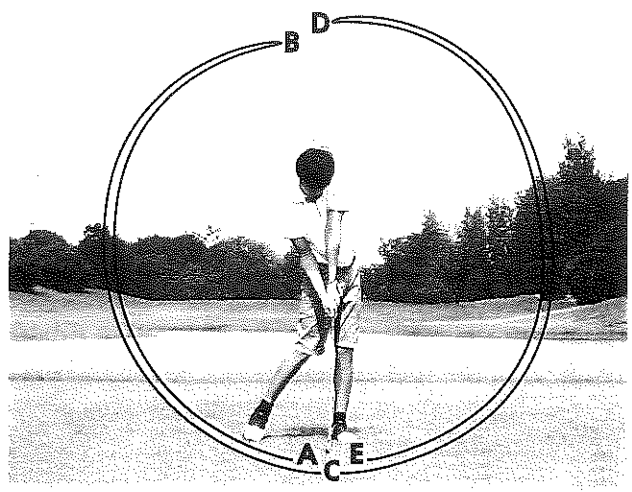
21. Exponents What is the value of 12^2?

22. Exponents What is the value of $2^2 \times 3^2$?

Applying Skills

Use the photo to answer Questions 23–25.

The golfer in the photo is taking a swing. The golf club starts at Point A and ends at Point E.



23. Inferring At which point(s) does the golf club have the greatest potential energy? At which point(s) does it have the greatest kinetic energy?

24. Interpreting Diagrams Describe the energy transformations from Point A to Point E.

25. Drawing Conclusions The kinetic energy of the club at Point C is more than the potential energy of the club at Point B. Does this mean that the law of conservation of energy is violated? Why or why not?

Lab zone Chapter Project

Performance Assessment Present your roller coaster to the class. Explain how you selected your materials, as well as the effect of hill height, incline, turns, and loops on the motion of the roller coaster. You should also explain how energy is transformed as the roller coaster moves along the tracks.

Standardized Test Prep

Test-Taking Tip

Watching for Qualifiers

Qualifiers are words like *most, least, greatest,* and *best*. When you answer a question with a qualifier, be sure to check and compare *all* the answer choices. Look for the answer that provides the information specified by the qualifier.

Sample Question

The table below gives the kinetic and potential energy of a 6-kg cat doing various activities.

Kinetic and Potential Energy of a Cat

Activity	Kinetic Energy (J)	Potential Energy (J)
Running	200	0
Leaping	150	100
Climbing a tree	3	300
Sleeping on a chair	0	30

The cat has the *greatest* mechanical energy when
- **A** it is running.
- **B** it is leaping.
- **C** it is climbing a tree.
- **D** it is sleeping on a chair.

Answer

The question asked for the cat's greatest mechanical energy. You can find the cat's mechanical energy for each activity by adding its kinetic and potential energy together. The values for climbing a tree (300 J + 3 J) give you the greatest sum (303 J). The answer is C.

Choose the letter of the best answer.

1. Wind has energy because
   - **A** it can change direction.
   - **B** it can do work.
   - **C** it has mass.
   - **D** it is electrically charged.

Use the table below and your knowledge of science to answer Questions 2 and 3.

Summer Classic Diving Competition

Name	Weight (N)	Height of Dive (m)
Clark	620	3
Simmons	640	3
Delgado	610	10
Chen	590	10

2. When standing on the diving board, which diver has the least gravitational potential energy?
   - **F** Clark
   - **G** Simmons
   - **H** Delgado
   - **J** Chen
3. In SI, which unit is used to express the divers' gravitational potential energy?
   - **A** newton
   - **B** kilowatt
   - **C** horsepower
   - **D** joule
4. A pendulum will eventually slow and stop because of
   - **F** friction.
   - **G** weight.
   - **H** kinetic energy.
   - **J** potential energy.
5. What energy transformation takes place when wood is burned?
   - **A** nuclear energy to thermal energy
   - **B** thermal energy to electrical energy
   - **C** chemical energy to thermal energy
   - **D** mechanical energy to thermal energy

Constructed Response

6. Explain the energy transformations involved in how fossil fuels formed and how they are used.