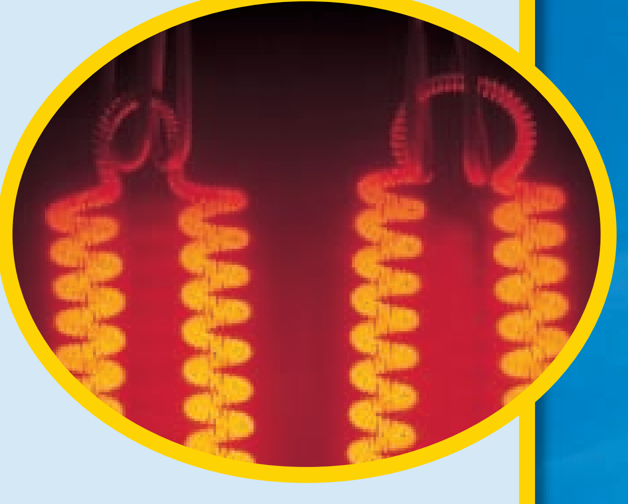
CHAPTER 4

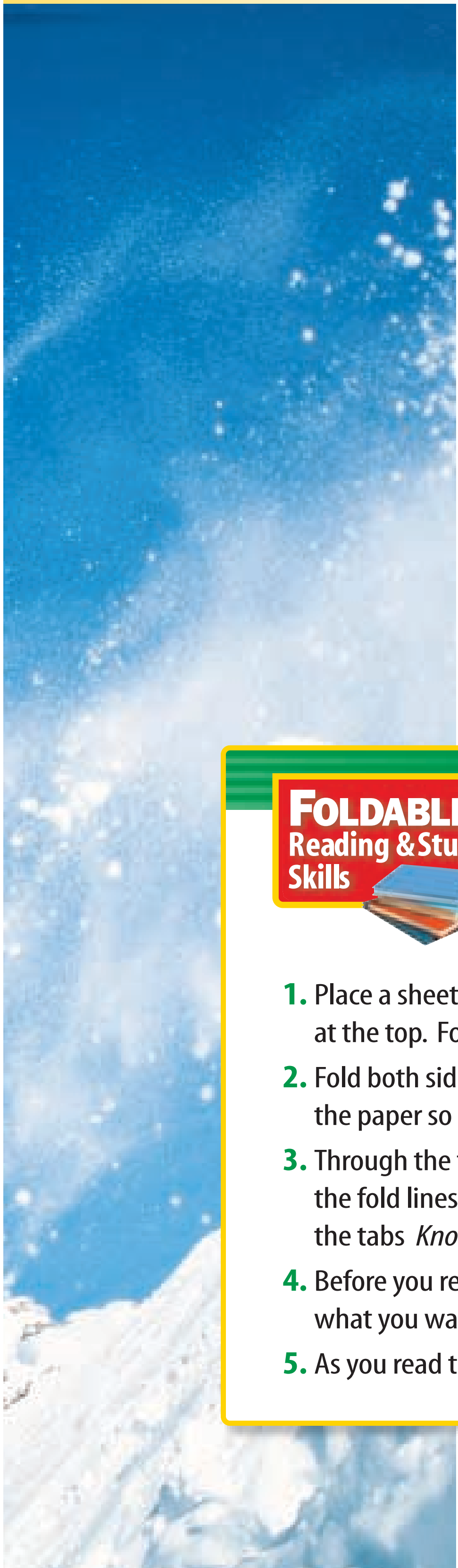
Energy

Snowboarding down the side of a mountain is an exhilarating experience. With little effort, you can easily reach speeds well over 50 km/h using nothing other than a snowboard, the slope, and a lot of snow. How do snowboarders achieve such high speeds? What supplies the energy to move them so fast? The answers to these questions can be found by studying energy and energy conservation.

What do you think?

Science Journal Look at the picture below with a classmate. Discuss what you think this might be or what is happening. Here's a hint: *It's used every day and allows people to work and play at any hour.* Write your answer or best guess in your Science Journal.





EXPLORE ACTIVITY

One of the most useful inventions of the nineteenth century was the electric lightbulb. Being able to light up the dark allows for extended work and recreation. A lightbulb uses electricity to produce light, but heat also is produced. To observe the conversion of electricity to light and heat, do the following activity.

Model how a lightbulb works

1. Obtain two D-cell batteries, two non-coated paper clips, tape, metal tongs and some steel wool. Separate the steel wool into thin strands and straighten the paper clips.
2. Tape the batteries together and then tape one end of each paper clip to the battery terminals as shown in the photograph.
3. While holding the strands of steel wool with the tongs, briefly complete the circuit by placing the steel wool in contact with both paper clip ends.

WARNING: *Steel wool can become hot—connect to battery only for a brief time.*

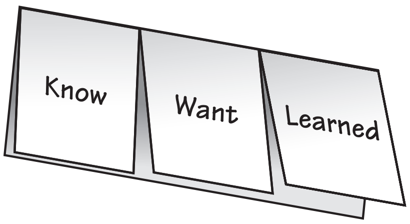
Observe

Describe in your Science Journal what you saw. Touch the steel wool. What changes are you observing?

Before You Read

FOLDABLES Reading & Study Skills

Making a Know-Want-Learn Study Fold **Make the following Foldable to help identify what you already know and what you want to know about energy.**



1. Place a sheet of paper in front of you so the long side is at the top. Fold the paper in half from top to bottom.
2. Fold both sides in to divide the paper into thirds. Unfold the paper so three sections show.
3. Through the top thickness of paper, cut along each of the fold lines to the top fold, forming three tabs. Label the tabs *Know, Want,* and *Learned,* as shown.
4. Before you read the chapter, write what you know about energy under the left tab and what you want to know under the middle tab.
5. As you read the chapter, write what you learn about energy under the right tab.

SECTION 1

The Nature of Energy

As You Read

What You'll Learn

- **Distinguish** between kinetic and potential energy.
- **Recognize** different ways that energy can be stored.

Vocabulary

kinetic energy
joule
potential energy
elastic potential energy
chemical potential energy
gravitational potential energy

Why It's Important

Understanding energy helps you understand how your environment is changing.

What is energy?

Wherever you are sitting as you read this, changes are taking place—lightbulbs are heating the air around them, the wind might be rustling leaves, or sunlight might be glaring off a nearby window. Even you are changing as you breathe, blink, or shift position in your seat.

Every change that occurs—large or small—involves energy. Imagine a baseball flying through the air. It hits a window, causing the glass to break as shown in **Figure 1.** The window changed from a solid sheet of glass to a number of broken pieces. The moving baseball caused this change—a moving baseball has energy. Even when you comb your hair or walk from class to class, energy is involved.

Change Requires Energy When something is able to change its environment or itself, it has energy. Energy is the ability to cause change. The moving baseball had energy. It certainly caused the window to change. Anything that causes change must have energy. You use energy to arrange your hair to look the way you want it to. You also use energy when you walk down the halls of your school between classes or eat your lunch. You even need energy to yawn, open a book, and write with a pen.

Figure 1
Each photo shows changes occurring.
Describe the changes that are occurring.

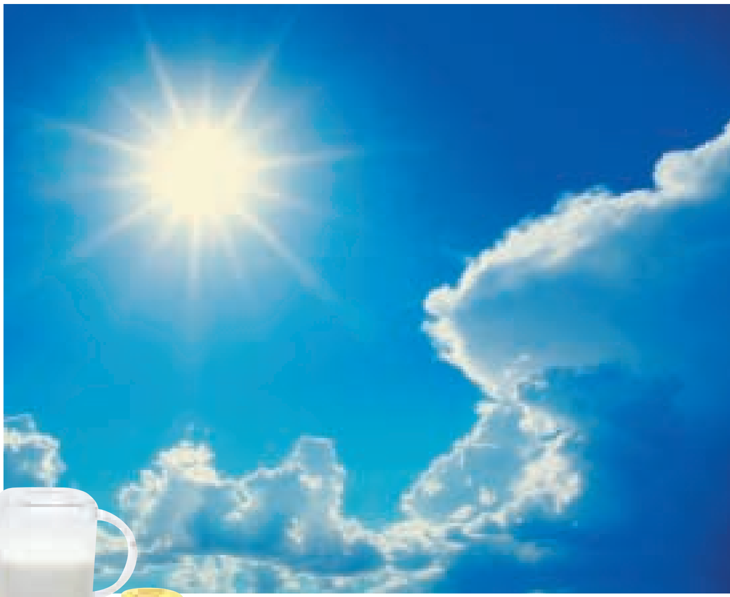


Figure 2
Energy can be stored in fuels, or it can travel through the environment. *Which objects are storing energy? Where is movement of energy occurring?*

Different Forms of Energy

Turn on an electric light, and a dark room becomes bright. Turn on your CD player, and sound comes through your headphones. In both situations, energy moves from one place to another. These changes seem to differ from each other and differ from a baseball shattering a window. This is because energy has several different forms, such as electrical, chemical, and thermal.

Figure 2 shows some examples of everyday situations in which you might notice energy. Is the chemical energy stored in food the same as the energy that comes from the Sun or the energy stored in gasoline? Thermal energy from the Sun travels a vast distance through space to Earth, warming the planet and providing energy that enables green plants to grow. When you make toast in the morning, you are using electrical energy. In short, energy plays a role in every activity that you do.

An Energy Analogy Money can be used in an analogy to help you understand energy. If you have $100, you could store it in a variety of forms—cash in your wallet, a bank account, travelers' checks, or gold or silver coins. You could transfer that money to different forms. You could deposit your cash into a bank account or trade the cash for gold. Regardless of its form, money is money. The same is true for energy. Energy from the Sun that warms you and energy from the food that you eat are only different forms of the same thing.

Reading Check *How is energy like money?*

SCIENCE Online

Collect Data Visit the Glencoe Science Web site at **science.glencoe.com** for more information about the kinetic energy of various animals. Communicate to your class what you learn.

CLICK HERE

Kinetic Energy

Usually, when you think of energy, you think of action—or some sort of motion taking place. **Kinetic energy** is energy in the form of motion. A spinning bicycle wheel, a sprinting runner, and a football passing through the goalposts all have kinetic energy, but the amounts depend on two quantities—the mass of the moving object and its velocity.

The more mass a moving object has, the more kinetic energy it has. Similarly, the greater an object's velocity is, the more kinetic energy it has. **Figure 3** shows a truck and a motorcycle that are moving at 100 km/h. Which vehicle has more kinetic energy? Although they have the same velocity, the truck has more kinetic energy because it has a greater mass than the motorcycle. **Figure 3** also shows two motorcycles—one moving at 100 km/h and one moving at 80 km/h. Which motorcycle has more kinetic energy? Assuming that the motorcycles have the same mass, the one moving at 100 km/h has greater kinetic energy than the one moving at 80 km/h.

Calculating Kinetic Energy

The kinetic energy of an object can be calculated using the following relationship.

$$\text{kinetic energy} = \frac{1}{2}\,\text{mass} \times \text{velocity}^2$$

$$KE\,(\text{J}) = \frac{1}{2}\,m\,(\text{kg}) \times v^2\,(\text{m}^2/\text{s}^2)$$

The **joule** (JEWL) is the SI unit of energy. It is named after the nineteenth-century British scientist James Prescott Joule. To calculate kinetic energy in joules (J), mass is measured in kilograms, and velocity is measured in meters per second.

Because velocity is squared in the equation for kinetic energy, increasing the velocity of an object can produce a large change in its kinetic energy. Without changing the mass of an object, doubling its velocity will quadruple its kinetic energy.

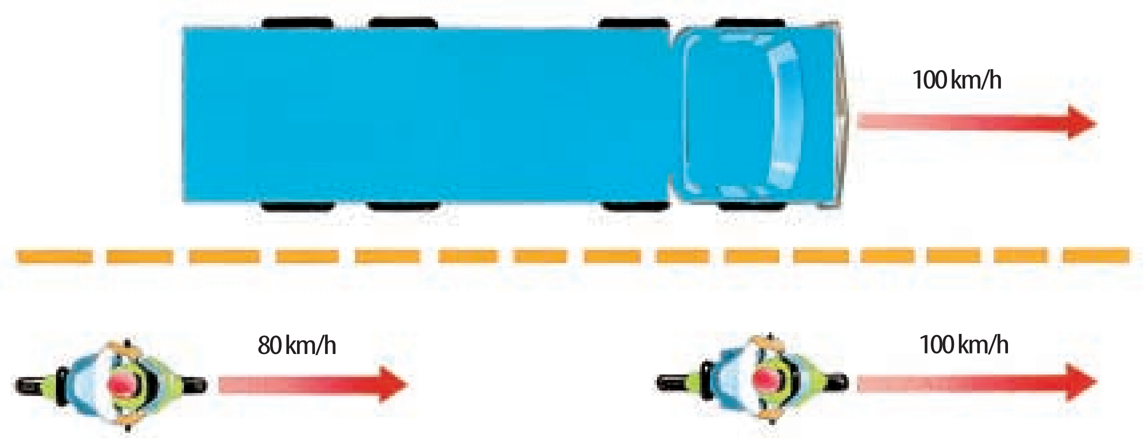
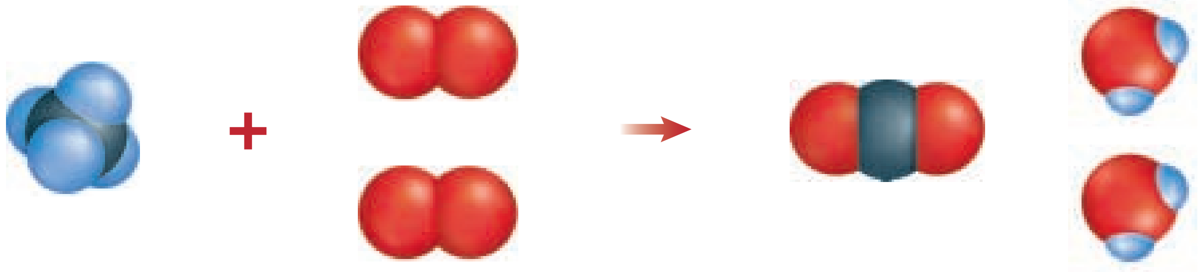


Figure 3
The kinetic energy of each vehicle is different because kinetic energy depends on an object's mass and its velocity.

CONTENTS

Figure 4
As natural gas burns, it combines with oxygen to form carbon dioxide and water. In this chemical reaction, chemical potential energy is released.



Potential Energy

Energy doesn't have to involve motion. Even motionless objects can have energy. This energy is stored in the object. Therefore, the object has potential to cause change. A hanging apple in a tree has stored energy. When the apple falls to the ground, a change occurs. Because the apple has the ability to cause change, it has energy. The hanging apple has energy because of its position above Earth's surface. Stored energy due to position is called **potential energy.** If the apple stays in the tree, it will keep the stored energy due to its height above the ground. If it falls, that stored energy of position is converted to energy of motion.

Elastic Potential Energy Energy can be stored in other ways, too. If you stretch a rubber band and let it go, it sails across the room. As it flies through the air, it has kinetic energy due to its motion. Where did this kinetic energy come from? Just as the apple hanging in the tree had potential energy, the stretched rubber band had energy stored as elastic potential energy. **Elastic potential energy** is energy stored by something that can stretch or compress, such as a rubber band or spring.

Chemical Potential Energy The cereal you eat for breakfast and the sandwich you eat at lunch also contain stored energy. Gasoline stores energy in the same way as food stores energy—in the chemical bonds between atoms. Energy stored in chemical bonds is **chemical potential energy. Figure 4** shows a molecule of natural gas. Energy is stored in the bonds that hold the carbon and hydrogen atoms together and is released when the gas is burned.

Reading Check *How is elastic potential energy different from chemical potential energy?*

Mini LAB

Interpreting Data from a Slingshot

Procedure

1. Using two fingers, carefully stretch a **rubber band** on a table until it has no slack.
2. Place a **nickel** on the table, slightly touching the midpoint of the rubber band.
3. Push the nickel back 0.5 cm and release. Measure the distance the nickel travels.
4. Repeat step 3, each time pushing the nickel back an additional 0.5 cm.

Analysis

1. How did the takeoff speed of the nickel seem to change relative to the distance that you stretched the rubber band?
2. What does this imply about the kinetic energy of the nickel?

Earth Science
INTEGRATION

Fast-flowing rivers and slow-moving glaciers have kinetic energy. A rock balanced on a hill contains potential energy. What are some other examples of kinetic and potential energy in nature?

Gravitational Potential Energy Gravity caused the apple to fall from the tree. Anything that can fall has stored energy called gravitational potential energy. **Gravitational potential energy** (GPE) is energy stored by objects that are above Earth's surface. The amount of gravitational potential energy depends on three things—the mass of the object, the acceleration due to gravity, and the height above the ground. The acceleration of gravity on Earth is 9.8 m/s^2, and the height is measured in meters.

The amount of gravitational potential energy an object has can be calculated using the following equation.

$$GPE = \text{mass} \times 9.8\ \text{m/s}^2 \times \text{height}$$

$$GPE\ (\text{J}) = m\ (\text{kg}) \times 9.8\ \text{m/s}^2 \times h\ (\text{m})$$

Just like kinetic energy, gravitational potential energy is measured in joules. All energy, no matter which form it is in, can be measured in joules.

Math Skills Activity

Calculating Gravitational Potential Energy

Example Problem

A 0.06-kg tennis ball starts to fall from a height of 2.9 m. How much gravitational potential energy does the ball have at that height?

Solution

1. *This is what you know:* mass of tennis ball: $m = 0.06$ kg; height of the tennis ball: $h = 2.9$ m; acceleration of gravity: 9.8 m/s^2
2. *This is what you want to find:* gravitational potential energy: GPE
3. *This is the equation you use:* $GPE = m \times 9.8\ \text{m/s}^2 \times h$
4. *Solve the equation by substituting the known values:* $GPE = 0.06\ \text{kg} \times 9.8\ \text{m/s}^2 \times 2.9\ \text{m} = 1.7\ \text{J}$

Check your answer by substituting it and the known values into the original equation. Do you get the same result?

Practice Problem

Bjorn is holding a tennis ball outside a second-floor window (3.5 m from the ground) and Billie Jean is holding one outside a third-floor window (6.25 m from the ground). How much more gravitational potential energy does Billie Jean's tennis ball have? (Each tennis ball has a mass of 0.06 kg.)

For more help, refer to the Math Skill Handbook.

Changing GPE Look at the objects on the bookshelf in **Figure 5.** Which of these objects has the most gravitational potential energy? According to the equation for gravitational potential energy, the GPE of an object can be increased by increasing its height above the ground. If two objects are at the same height, then the object with the larger mass has more gravitational potential energy.

In **Figure 5,** suppose the green vase on the lower shelf and the blue vase on the upper shelf have the same mass. Then the vase that is on the upper shelf has more gravitational potential energy because it is higher above the ground.

Imagine what would happen if the two vases were to fall. As they fall and begin moving, they have kinetic energy as well as gravitational potential energy. As the vases get closer to the ground, their gravitational potential energy decreases. At the same time they are moving faster, so their kinetic energy increases. The vase that initially had more gravitational potential energy will be moving faster when it hits the floor.

Do the books on the shelf above the green vase have more gravitational potential energy than the vase? That depends on the mass of the books. Even though they are twice as high as the vase, their gravitational potential energy also depends on their mass. If the mass of the books is less than half the mass of the vase, then the books have less gravitational potential energy, even though they are at a greater height.

Reading Check *What does GPE depend on?*

Figure 5
An object's gravitational potential energy increases with increased height. *Which vase has more gravitational potential energy? Which one will have more kinetic energy when it strikes the ground?*

Section 1 Assessment

1. Two books with different masses fall off the same bookshelf. As they fall, which has more kinetic energy and why?
2. How can the gravitational potential energy of an object be changed?
3. How is energy stored in food? Is the form of energy stored in food different from the form stored in gasoline? Explain.
4. Contrast potential and kinetic energy.
5. **Think Critically** The food you eat supplies energy for your body. Suggest ways your body might make use of this energy.

Skill Builder Activities

6. **Comparing and Contrasting** Compare and contrast elastic potential energy, chemical potential energy, and gravitational potential energy. **For more help, refer to the Science Skill Handbook.**
7. **Solving One-Step Equations** An 80-kg diver jumps off a 10-m platform. Calculate how much gravitational potential energy the diver has at the top of the platform and halfway down. **For more help, refer to the Math Skill Handbook.**

Activity

Bouncing Balls

What happens when you drop a ball onto a hard, flat surface? It starts with potential energy. It bounces up and down until it finally comes to a rest. Where did the energy go?

What You'll Investigate

How do balls differ in their bouncing behavior?

Materials

tennis ball	masking tape
rubber ball	cardboard box
balance	**shoe box*
meterstick	**Alternate materials*

Goals

- **Identify** the forms of energy observed in a bouncing ball.
- **Infer** why the ball stops bouncing.

Safety Precautions

Procedure

1. **Measure** the mass of the two balls.
2. Have a friend drop one ball from 1 m. Measure how high the ball bounced. Repeat this two more times so that you can calculate an average bounce height. Record your values on the data table.
3. Repeat step 2 for the other ball.
4. **Predict** whether the balls would bounce higher or lower if they were dropped onto the cardboard box. Design an experiment to measure how high the balls would bounce off the surface of a cardboard box.

Bounce Height

Type of Ball	Surface	Trial	Height (cm)
Tennis	Floor	1	
Tennis	Floor	2	
Tennis	Floor	3	
Rubber	Floor	1	
Rubber	Floor	2	
Rubber	Floor	3	
Tennis	Box	1	

Conclude and Apply

1. **Calculate** the gravitational potential energy of each ball before dropping them.
2. As the balls fall, what happens to their gravitational potential energy and their kinetic energy? What happens to their kinetic energy when they hit the floor?
3. **Calculate** the average bounce height for the three trials under each condition. Describe your observations.
4. How did the bounce heights compare when dropped on a cardboard box instead of the floor? Why? Hint: *Did you observe any movement of the box when the balls bounced?*
5. Use elastic potential energy to explain why the balls bounced to different heights.

Communicating Your Data

Meet with three other lab teams and compare average bounce heights for the tennis ball on the floor. Discuss why your results might differ. **For more help, refer to the Science Skill Handbook.**

SECTION

2 Conservation of Energy

Changing Forms of Energy

Unless you were talking about potential energy, you probably wouldn't think of the book on top of a bookshelf as having much to do with energy—until it fell. You'd be more likely to think of energy as race cars roar past or as your body uses energy from food to help it move, or as the Sun warms your skin on a summer day. You might be thankful for electrical energy as you play a favorite CD. These situations involve energy changing from one form to another form. Energy is most noticeable as it transforms from one type to another.

Transforming Electrical Energy You use many devices every day that convert one form of energy to other forms. For example, you might be reading this page in a room lit by lightbulbs. The lightbulbs transform electrical energy into light so you can see. The warmth you feel around the bulb is evidence that some of that electrical energy is turned into thermal energy, as illustrated in **Figure 6.** What other devices have you used today that make use of electrical energy? You might have been awakened by an alarm clock, styled your hair, made toast, listened to music, or played a video game. What form or forms of energy is electrical energy converted to in these examples?

As You Read

What You'll Learn

- **Describe** how energy is conserved when changing from one form to another.
- **Apply** the law of conservation of energy to familiar situations.

Vocabulary

mechanical energy
law of conservation of energy

Why It's Important

Conservation of energy is a universal principle that can explain how energy changes occur.

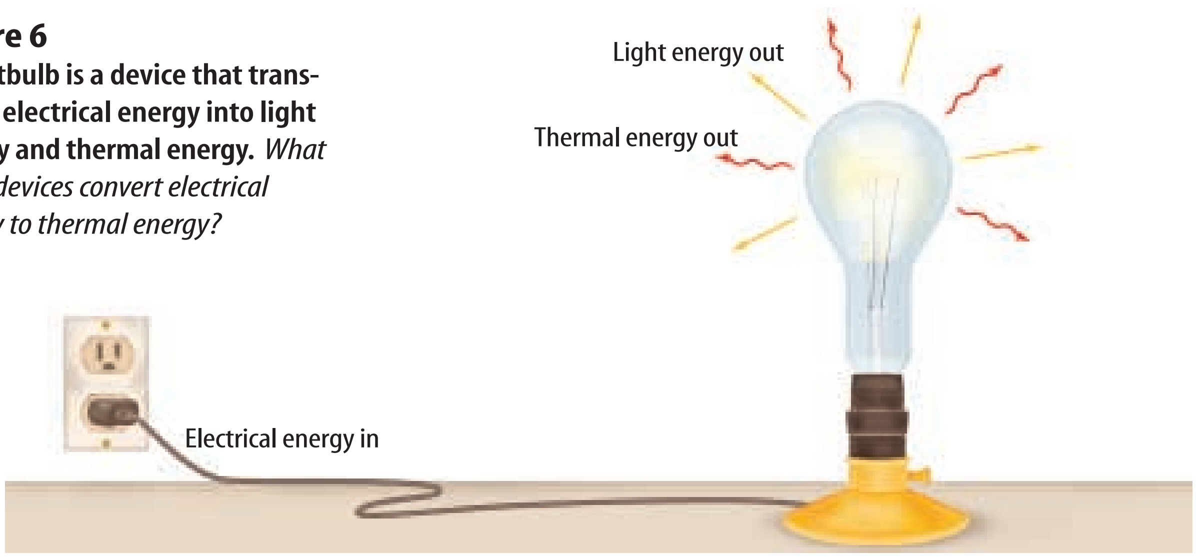


Figure 6
A lightbulb is a device that transforms electrical energy into light energy and thermal energy. *What other devices convert electrical energy to thermal energy?*


Spark plug fires


Gases expand

Figure 7

A **In a car, a spark plug fires, initiating the conversion of chemical potential energy into thermal energy.**

B **As the hot gases expand, thermal energy is converted into kinetic energy.**

Transforming Chemical Energy Fuel stores energy in the form of chemical potential energy. For example, the car or bus that might have brought you to school this morning probably runs on gasoline. The engine transforms the chemical potential energy stored in gasoline into the kinetic energy of a moving car or bus. Several energy conversions occur in this process, as shown in **Figure 7.** An electrical spark ignites a small amount of fuel. The burning fuel produces thermal energy. So chemical energy is changed to thermal energy. The thermal energy causes gases to expand and move parts of the car, producing kinetic energy.

Some energy transformations are less obvious because they do not result in visible motion, sound, heat, or light. Every green plant you see converts light energy from the Sun into energy stored in chemical bonds in the plant. If you eat an ear of corn, the chemical potential energy in the corn is transformed yet again when it is in your body.

Conversions Between Kinetic and Potential Energy

You have experienced many situations that involve conversions between potential and kinetic energy. Bicycles, roller coasters, and swings can be described in terms of potential and kinetic energy. Even something as simple as launching a rubber band or using a bow and arrow involves energy conversions. To understand the energy conversions in these activities, it is helpful to identify the mechanical energy of a system. **Mechanical energy** is the total amount of potential and kinetic energy in a system and can be expressed by this equation.

$$\text{mechanical energy} = \text{potential energy} + \text{kinetic energy}$$

In other words, mechanical energy is energy due to the position and the motion of an object. What happens to the mechanical energy of an object as potential and kinetic energy are converted into each other?

Falling Objects Standing under an apple tree can be hazardous. Here is an explanation of why this is true using energy terms. An apple on a tree, like the one in **Figure 8,** has gravitational potential energy due to Earth pulling down on it. The apple does not have kinetic energy while it hangs from the tree. However, the instant the apple comes loose from the tree, it accelerates due to gravity. As it falls, it loses height so its gravitational potential energy decreases. This potential energy is not lost. Rather, it is transformed into kinetic energy as the velocity of the apple increases.

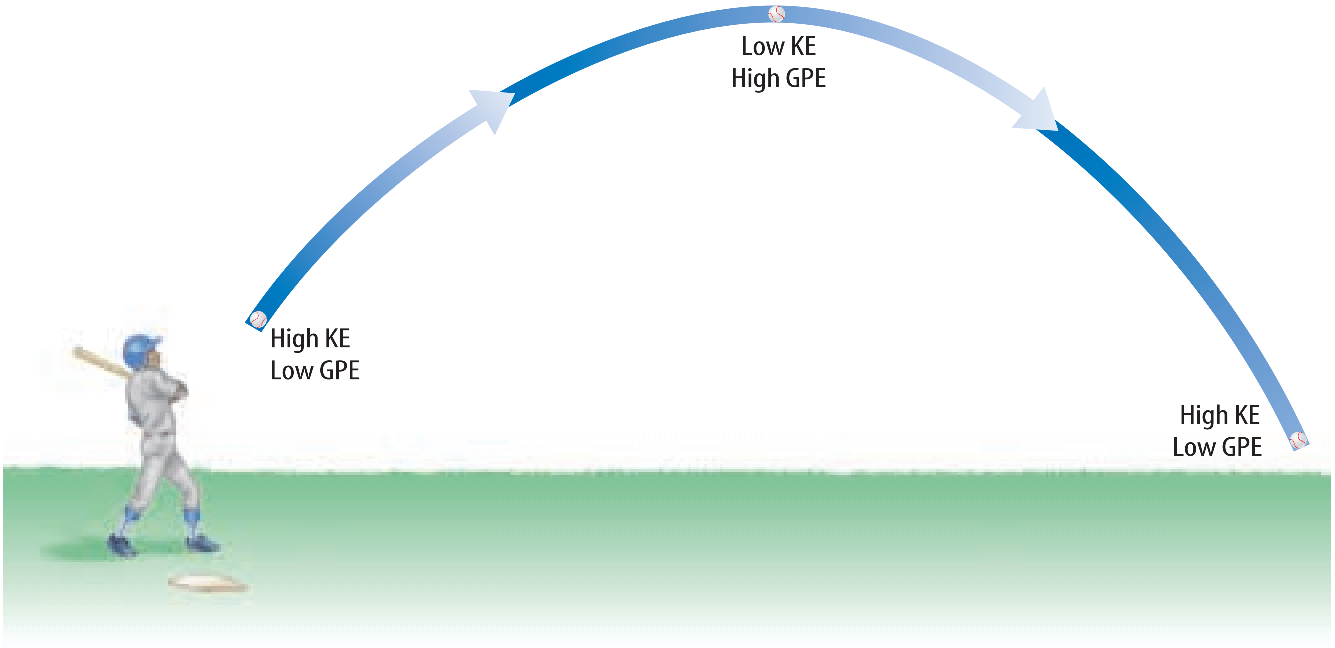
Look back at the equation for mechanical energy. If the potential energy is being converted into kinetic energy, then the mechanical energy of the apple doesn't change as it falls. The potential energy that the apple loses is gained back as kinetic energy. The form of energy changes, but the total amount of energy remains the same.

Reading Check *What happens to the mechanical energy of the apple as it falls from the tree?*

Energy transformation also occurs when a baseball is hit into the air. Look at **Figure 9.** When the ball leaves the bat, it has mostly kinetic energy. As the ball rises, its velocity decreases, so its kinetic energy must decrease, too. However, the ball's gravitational potential energy increases as it goes higher. At its highest point, the baseball has the maximum amount of gravitational potential energy. The only kinetic energy it has at this point is due to its forward motion. Then, as the baseball falls, gravitational potential energy decreases while kinetic energy increases as the ball moves faster. Once again, the mechanical energy of the ball remains constant as it rises and falls.

Figure 8
Objects that can fall have gravitational potential energy.
What objects around you have gravitational potential energy?

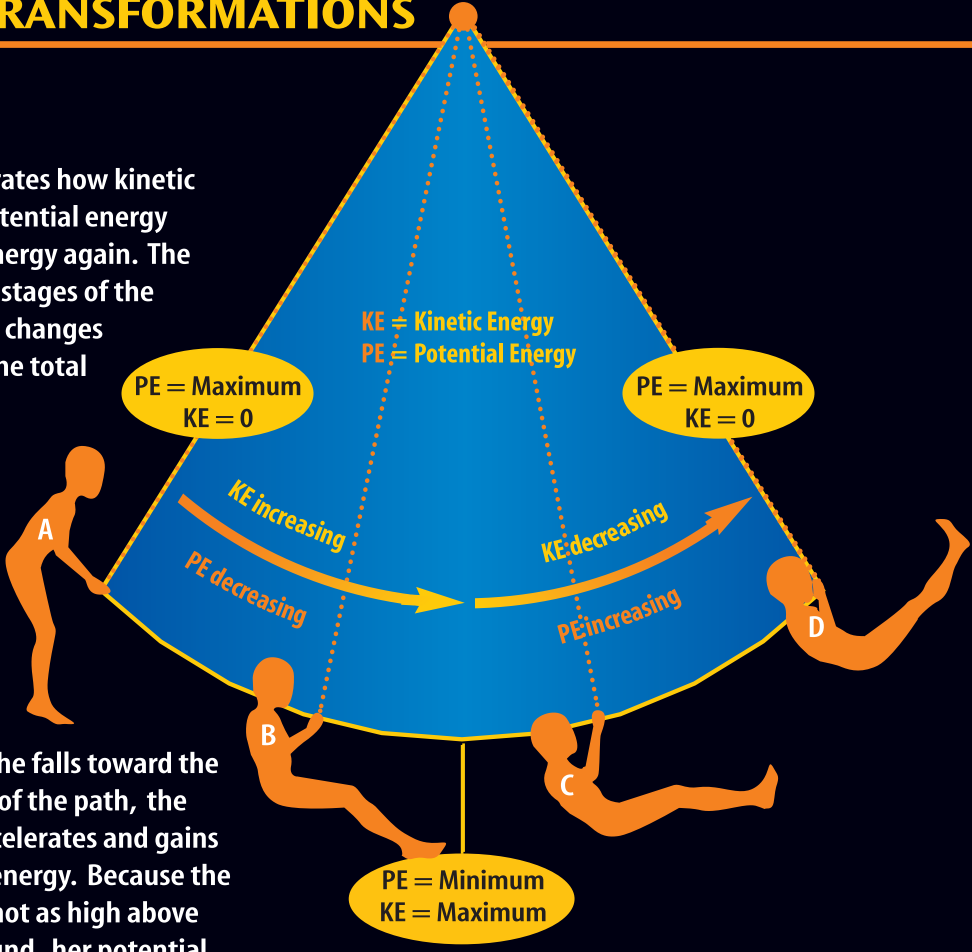
Figure 9
A ball hit into the air illustrates how kinetic energy and gravitational potential energy are converted into each other.



VISUALIZING ENERGY TRANSFORMATIONS

Figure 10

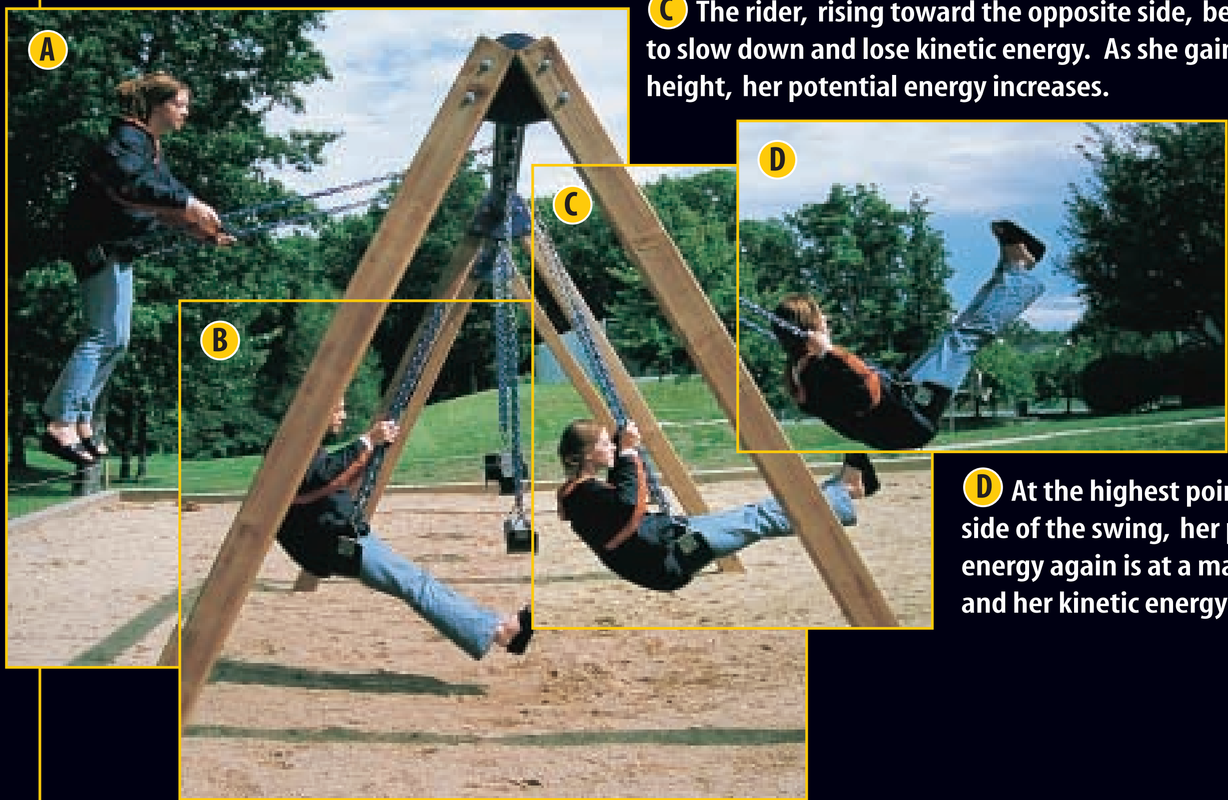
A ride on a swing illustrates how kinetic energy changes to potential energy and back to kinetic energy again. The diagram at right shows four stages of the swing's motion. Although it changes from one form to another, the total energy remains the same.



A At the rider's highest point, her potential energy is at a maximum and her kinetic energy is zero.

B As she falls toward the bottom of the path, the rider accelerates and gains kinetic energy. Because the rider is not as high above the ground, her potential energy decreases.

C The rider, rising toward the opposite side, begins to slow down and lose kinetic energy. As she gains height, her potential energy increases.



D At the highest point on this side of the swing, her potential energy again is at a maximum, and her kinetic energy is zero.

Swinging Along When you ride on a swing, like the one shown in **Figure 10,** part of the fun is the feeling of almost falling as you drop from the highest point to the lowest point of the swing's path. Think about energy conservation to analyze such a ride.

The ride starts with a push that gets you moving, giving you some kinetic energy. As the swing rises, you lose speed but gain height. In energy terms, kinetic energy changes to gravitational potential energy. At the top of your path, potential energy is at its greatest. Then, as the swing accelerates downward, potential energy changes to kinetic energy. At the bottom of each swing, the kinetic energy is at its greatest and the potential energy is at its minimum. As you swing back and forth, energy continually converts from kinetic to potential and back to kinetic. What happens to your mechanical energy as you swing?

The Law of Conservation of Energy

When a ball is thrown into the air or a swing moves back and forth, kinetic and potential energy are constantly changing as the object speeds up and slows down. However, mechanical energy stays constant. Kinetic and potential energy simply change forms and no energy is destroyed.

This is always true. Energy can change from one form to another, but the total amount of energy never changes. Even when energy changes form from electrical to thermal and other energy forms as in the hair dryer shown in **Figure 11,** energy is never destroyed. Another way to say this is that energy is conserved. This principle is recognized as a law of nature. The **law of conservation of energy** states that energy cannot be created or destroyed. On a large scale, this law means that the total amount of energy in the universe remains constant.

Reading Check *What law states that the total amount of energy never changes?*

You might have heard about energy conservation or been told to conserve energy. These ideas are related to reducing the demand for electricity and gasoline, which lowers the consumption of energy resources such as coal and fuel oil. The law of conservation of energy, on the other hand, is a universal principle that describes what happens to energy as it is transferred from one object to another or as it is transformed.

Environmental Science INTEGRATION

One way energy enters ecosystems is when green plants transform radiant energy from the Sun into chemical potential energy in the form of food. Energy moves through the food chain as animals that eat plants are eaten by other animals. Some energy leaves the food chain, such as when living organisms release thermal energy to the environment. Diagram a simple biological food chain showing energy conservation.

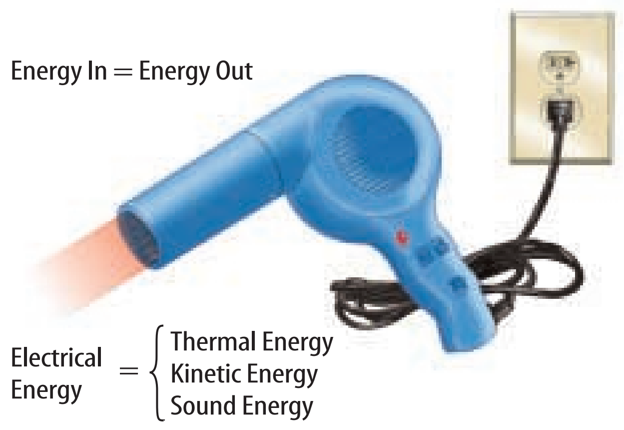
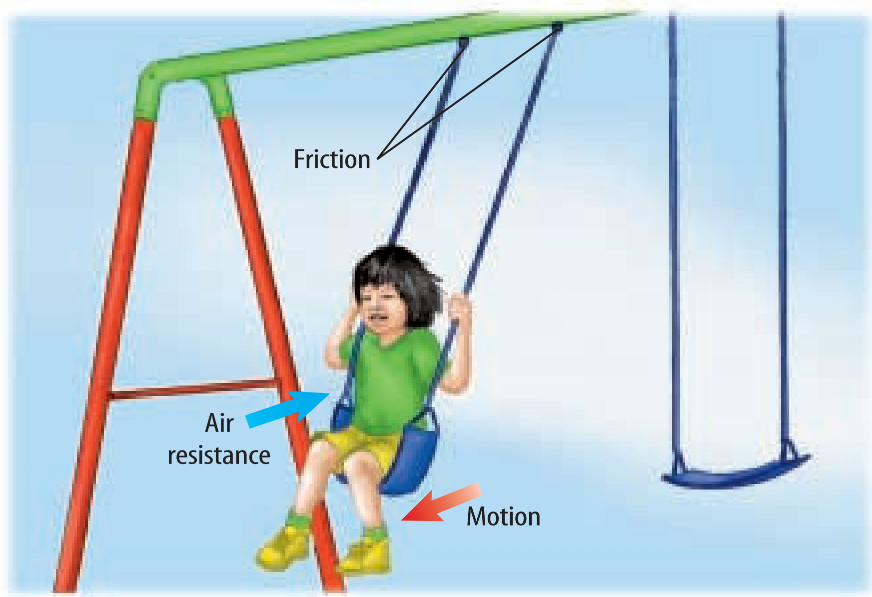


Figure 11
The law of conservation of energy requires that the total amount of energy going into a hair dryer must equal the total amount of energy coming out of the hair dryer.

Figure 12
In a swing, mechanical energy is transformed into thermal energy because of friction and air resistance.



TRY AT HOME

Mini LAB

Transforming Energy Using a Paper Clip

Procedure

1. Straighten a **paper clip.** While holding the ends, touch the paper clip to the skin just below your lower lip. Note whether the paper clip feels warm, cool, or about room temperature.
2. Quickly bend the paper clip back and forth five times. Touch it below your lower lip again. Note whether the paper clip feels warmer or cooler than before.

Analysis

1. What happened to the temperature of the paper clip? Why?
2. As you bend the paper clip, explain all the energy conversions that take place.

Friction and the Law of Conservation of Energy You might be able to think of situations where it seems as though energy is not conserved. For example, while coasting along a flat road on a bicycle, you know that you will eventually stop if you don't pedal. If energy is conserved, why wouldn't your kinetic energy stay constant so that you would coast forever? In many situations, it might seem that energy is destroyed or created. Sometimes it is hard to see the law of conservation of energy at work.

Following Energy's Trail You know from experience that if you don't continue to pump a swing or be pushed by somebody else, your arcs will become lower and you eventually will stop swinging. In other words, the mechanical (kinetic and potential) energy of the swing seems to decrease, as if the energy were being destroyed. Is this a violation of the law of conservation of energy?

It can't be—it's the law! If the energy of the swing decreases, then the energy of some other object must increase by an equal amount to keep the total amount of energy the same. What could this other object be that experiences an energy increase? To answer this, you need to think about friction. With every movement, the swing's ropes or chains rub on their hooks and air pushes on the rider, as illustrated in **Figure 12.** Friction and air resistance cause some of the mechanical energy of the swing to change to thermal energy. With every pass of the swing, the temperature of the hooks and the air increases a little, so the mechanical energy of the swing is not destroyed. Rather, it is transformed into thermal energy. The total amount of energy always stays the same.

Converting Mass into Energy You might have wondered how the Sun unleashes enough energy to light and warm Earth from so far away. A special kind of energy conversion—nuclear fusion—takes place in the Sun and other stars. During this process a small amount of mass is transformed into a tremendous amount of energy. An example of a nuclear fusion reaction involving hydrogen nuclei is shown in **Figure 13A.**

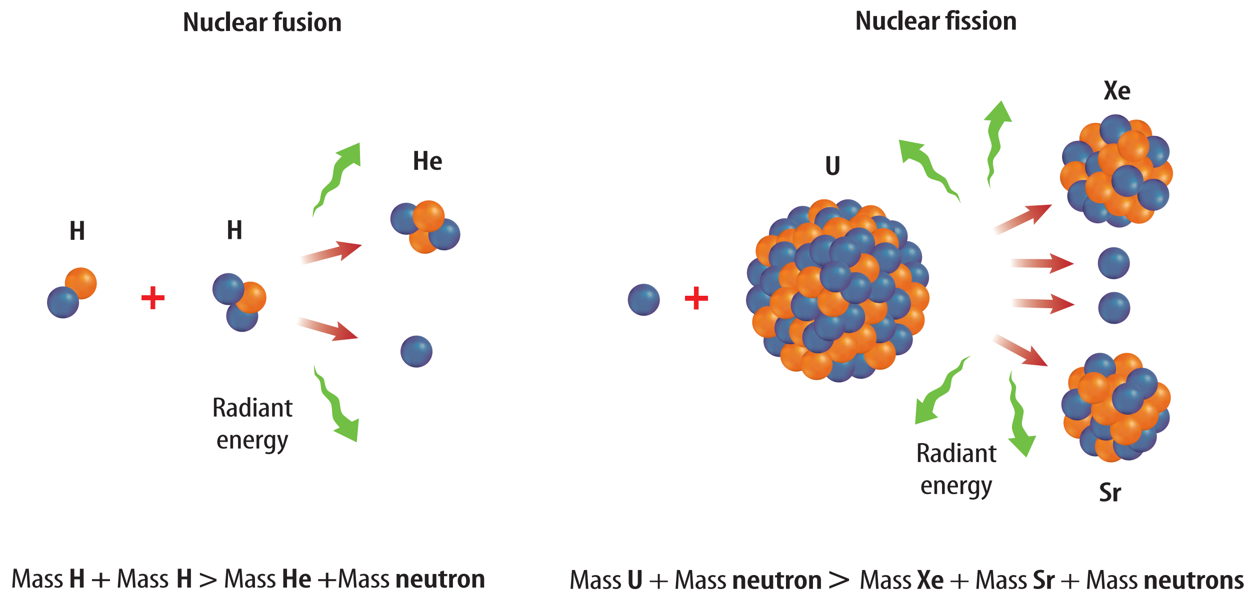
Nuclear Fission Another process involving the nuclei of atoms, called nuclear fission, converts a small amount of mass into enormous quantities of energy. In this process, nuclei do not fuse—they are broken apart, as shown in **Figure 13B.** In either process, fusion or fission, mass is converted to energy. You must think of mass as energy when applying the law of conservation of energy to processes involving nuclear reactions. Here, as in all cases, the total amount of mass and energy is conserved. The process of nuclear fission is used by nuclear power plants to generate electrical energy. The fission process occurs in a nuclear reactor, and the heat released changes water to steam. The steam is used to spin an electric generator.

SCIENCE Online

Research Visit the Glencoe Science Web site at **science.glencoe.com** for more information about the role of friction in the design of automobiles. Communicate to your class what you learn.

CLICK HERE

Figure 13
Mass is converted to energy in the processes of fusion and fission.



A **In this fusion reaction, the combined mass of the two hydrogen nuclei, H, is greater than the mass of the helium nucleus, He, and the neutron.**

B **In nuclear fission, the mass of the large nucleus on the left is greater than the combined mass of the other two nuclei and the neutrons.** *Why aren't the masses equal?*

The Human Body—Balancing the Energy Equation

What forms of energy discussed in this chapter can you find in the human body? With your right hand, reach up and feel your left shoulder. With that simple action, stored potential energy within your body was converted to the kinetic energy of your moving arm. Did your shoulder feel warm to your hand? Some of the potential energy stored in your body is used to maintain a nearly constant internal temperature. A portion of this energy also is converted to the excess heat that your body gives off to its surroundings. Even the people shown standing in **Figure 14** require energy conversions to stand still.

Energy Conversions in Your Body The complex chemical and physical processes going on in your body also obey the law of conservation of energy. Your body stores energy in the form of fat and other chemical compounds. This chemical potential energy is used to fuel the processes that keep you alive, such as making your heart beat and digesting the food you eat. Your body also converts this energy to heat that is transferred to your surroundings, and you use this energy to make your body move. **Table 1** shows the amount of energy used in doing various activities. To maintain a healthy weight, you must have a proper balance between energy contained in the food you eat and the energy your body uses.

Figure 14
The runners convert the energy stored in their bodies more rapidly than the spectators do.
*Use **Table 1** to calculate how long a person would need to stand to burn as much energy as a runner burns in 1 h.*

Health INTEGRATION

Food—Your Chemical Potential Energy

Your body has been busy breaking down your breakfast into molecules that can be used as fuel. These fuel molecules, such as sugar, supply all the cells in your body with the energy they need to function. If you did not eat breakfast this morning, your body will convert energy stored in fat for its immediate needs until you eat again. The food Calorie (C) is a unit used by nutritionists to measure how much energy you get from various foods—1 C is equivalent to about 4,184 J. Every gram of fat a person consumes can supply 9 C of energy. Carbohydrates and proteins each supply about 4 C of energy per gram. The next time you go grocery shopping, look on the packages and notice how much energy each product eventually will supply to you.

Table 1 Calories Used in 1 h

Type of Activity	Body Frames		
	Small	Medium	Large
Sleeping	48	56	64
Sitting	72	84	96
Eating	84	98	112
Standing	96	112	123
Walking	180	210	240
Playing tennis	380	420	460
Bicycling (fast)	500	600	700
Running	700	850	1,000

Section 2 Assessment

1. Define the term *mechanical energy.* Describe the mechanical energy of a roller-coaster car immediately before it begins traveling down a long track.
2. What is the law of conservation of energy?
3. Applying bicycle brakes as you ride down a long hill causes the brake pads and the wheel rims to feel warm. Explain.
4. What is the source of the large amounts of energy released in nuclear reactors and in the Sun? Are the same processes occurring in the Sun and in reactors? Explain.
5. **Think Critically** Much discussion has focused on the need to drive more efficient cars and use less electricity. If the law of conservation of energy is true, why are people concerned about energy usage?

Skill Builder Activities

6. **Communicating** Suppose you drop a tennis ball out of a second-floor window. The first bounce will be the highest. Each bounce after that will be lower until the ball stops bouncing. Write a description of the energy conversions that take place, starting with dropping the ball. Accompany your description with an appropriate illustration. **For more help, refer to the Science Skill Handbook.**
7. **Communicating** Your body used energy as you walked into your school today. Where did this energy come from? In your Science Journal, write a paragraph describing where you acquired this energy. Trace it back through as many transformations as you can. **For more help, refer to the Science Skill Handbook.**

Activity
Design Your Own Experiment

Swinging Energy

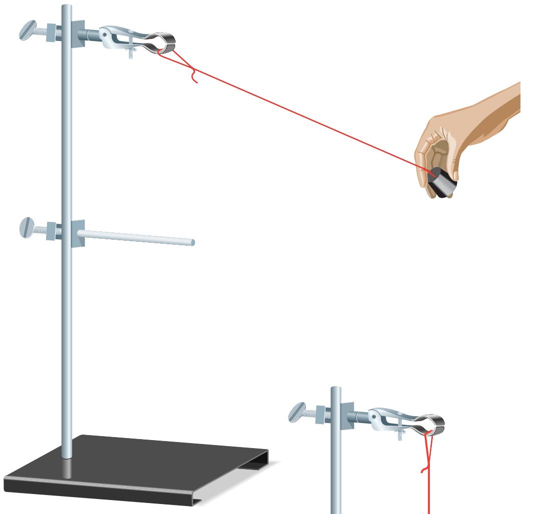
Imagine yourself swinging on a swing. What would happen if a friend grabbed the swing's chains as you passed the lowest point? Would you come to a complete stop or continue rising to your previous maximum height?

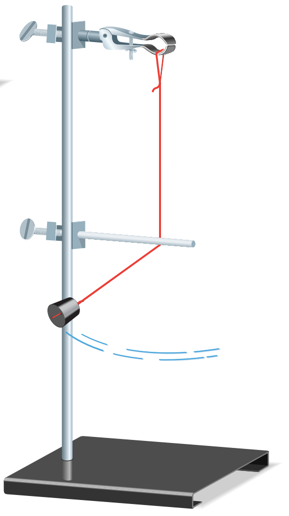
Recognize the Problem

How does the motion and maximum height reached by a swing change if the swing is interrupted?

Form a Hypothesis

Examine the diagram on this page. How is it similar to the situation in the introductory paragraph? An object that is suspended so that it can swing back and forth also is called a pendulum. Hypothesize what will happen to the pendulum's motion and final height if its swing is interrupted.





Goals

- **Construct** a pendulum to compare the exchange of potential and kinetic energy when a swing is interrupted.
- **Measure** the starting and ending heights of the pendulum.

Possible Materials

test-tube clamp
ring stand
support-rod clamp, right angle
30-cm support rod
2-hole, medium rubber stopper
string (1 m)
metersticks
graph paper

Safety Precautions

Be sure the base is heavy enough or well anchored so that the apparatus will not tip over.

Test Your Hypothesis

Plan

1. As a group, write your hypothesis and list the steps that you will take to test it. Be specific. Also list the materials you will need.
2. **Design** a data table and place it in your Science Journal.
3. Set up an apparatus similar to the one shown in the diagram.
4. **Devise** a way to measure the starting and ending heights of the stopper. Record your starting and ending heights in a data table. This will be your control.
5. **Decide** how to release the stopper from the same height each time.
6. Be sure you test your swing, starting it above and below the height of the cross arm. How many times should you repeat each starting point?

Do

1. Make sure your teacher approves your plan before you start.
2. Carry out the approved experiment as planned.
3. While the experiment is going on, write any observations that you make and complete the data table in your Science Journal.

Analyze Your Data

1. When the stopper is released from the same height as the cross arm, is the ending height of the stopper exactly the same as its starting height? Use your data to support your answer.
2. **Analyze** the energy transfers. At what point along a single swing does the stopper have the greatest kinetic energy? The greatest potential energy?

Draw Conclusions

1. Do the results support your hypothesis? Explain.
2. **Compare** the starting heights to the ending heights of the stopper. Is there a pattern? Can you account for the observed behavior?
3. Do your results support the law of conservation of energy? Why or why not?
4. What happens if the mass of the stopper is increased? Test it.

Communicating Your Data

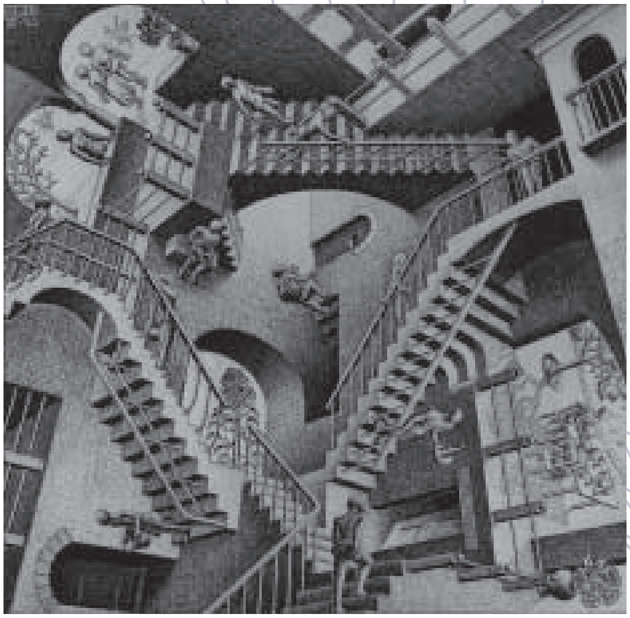
Compare your conclusions with those of the other lab teams in your class. **For more help, refer to the Science Skill Handbook.**

The Impossible Dream

A machine that keeps on going? It has been tried for hundreds of years.

Science is a bit like an easygoing parent—it doesn't lay down a lot of laws. Those laws that do exist, however, are hard to get around. Just ask the hundreds of people who have tried throughout history—and failed—to build perpetual-motion machines.

In theory, a perpetual-motion machine would run forever and do work without a continual source of energy. You can think of it as a car that you could fill up once with gas, and with that single tankful, the car would run forever. Sound impossible? It is!



Artist M.C. Escher drew this never-ending staircase. You could walk on it perpetually!

Visitors look at the Keely Motor, the most famous perpetual-motion machine fraud of the late 1800s.

Science Puts Its Foot Down

For hundreds of years, people have tried to create perpetual-motion machines. But these machines won't work because they violate two of nature's laws. The first law is the law of conservation of energy, which states that energy cannot be created or destroyed. It can change form—say, from mechanical energy to electrical energy—but you always end up with the same amount of energy that you started with.

How does that apply to perpetual-motion machines? When a machine does work on an object, the machine transfers energy to the object. Unless that machine gets more energy from somewhere else, it can't keep doing work. If it did, it would be creating energy.

The second law states that heat by itself always flows from a warm object to a cold object. Heat will only flow from a cold object to a warm object if work is done. In the process, some heat always escapes. The hood of a car, for instance, feels hot when the car is running. That's because heat, or thermal energy has escaped from the car's engine.

To make up for these energy losses, energy constantly needs to be transferred to the machine. Otherwise, it stops. No perpetual motion. No free electricity. No devices that generate more energy than they use. No engine motors that run forever without fuel. No lights that shine or ships that sail without a continual source of energy. Some laws just can't be broken.

Losing Battles

For more than 300 years, people have tried to build a perpetual-motion machine that works. Nobody has ever succeeded. In fact, the U.S. Patent Office, which studies inventions to see if they work before they grant a patent, refuses to even look at machines that their inventors claim are perpetual-motion machines.

Some laws just can't be broken.

CONNECTIONS Analyze Using your school or public library resources, locate a picture or diagram of a perpetual-motion machine. Figure out why it won't run forever. Explain to the class what the problem is.

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SCIENCE Online
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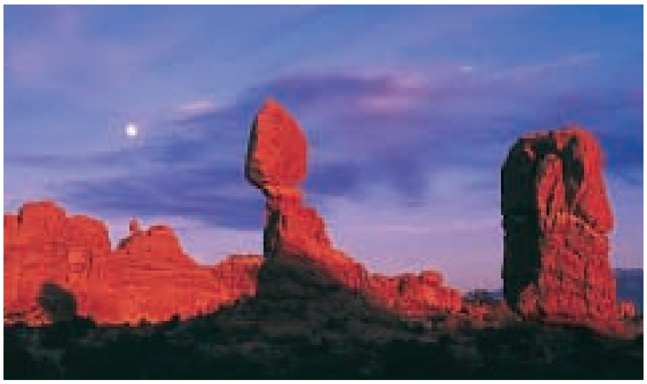
CONTENTS

Reviewing Main Ideas

Section 1 The Nature of Energy

1. Energy is the ability of something to cause change.
2. Energy can take a variety of different forms. *What are some of the forms of energy illustrated in the photograph below?*

3. Moving objects have kinetic energy that depends on the mass of the object and the velocity of the object.
4. Potential energy is stored energy. Objects that can fall have gravitational potential energy—the amount depends on their weight and height above the ground. *If Balanced Rock, shown in the photograph below, fell, how would its gravitational potential energy change?*



Section 2 Conservation of Energy

1. Energy can change from one form to another. You observe many energy transformations every day.
2. The law of conservation of energy states that energy never can be created or destroyed. Because of friction, energy might seem to be lost, but it has changed into thermal energy.
3. Falling, flying, and swinging objects all involve transformations between potential and kinetic energy. The total amount of potential and kinetic energy is called mechanical energy. *What energy transformations are taking place in the figure below? Is energy being conserved?*

4. Mass can be converted into energy in nuclear fusion and fission reactions. Fusion and fission involve atomic nuclei and release tremendous amounts of energy.

After You Read

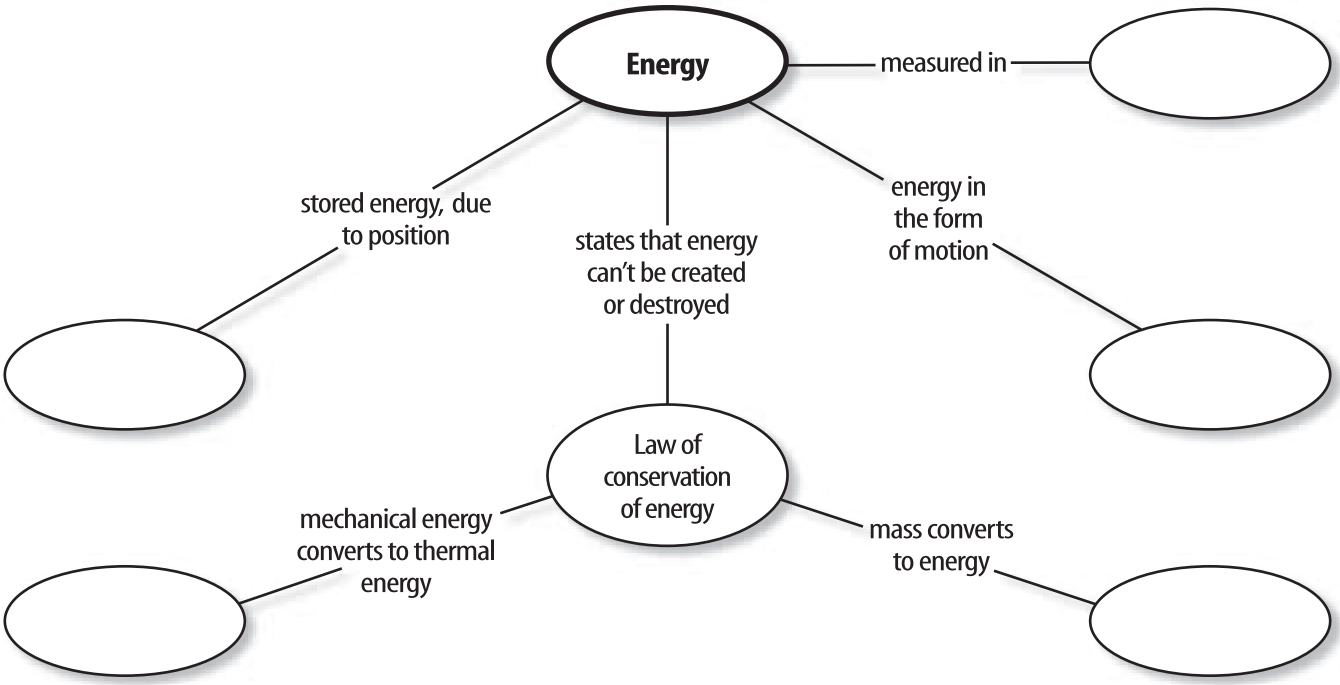
FOLDABLES Reading & Study Skills

To help review what you've learned about energy and energy conservation, use the Foldable you made at the beginning of the chapter.

CONTENTS

Visualizing Main Ideas

Complete the concept map below using the following terms: nuclear fusion/fission, potential energy, friction, joules, kinetic energy.



Vocabulary Review

Vocabulary Words

a. chemical potential energy
b. elastic potential energy
c. gravitational potential energy
d. joule
e. kinetic energy
f. law of conservation of energy
g. mechanical energy
h. potential energy

THE PRINCETON REVIEW Study Tip

Be a teacher! Get together a group of friends and assign each person a section of the chapter to teach. When you teach you remember and understand information thoroughly.

Using Vocabulary

Using the list of vocabulary words, replace the underlined words with the correct science term.

1. In describing the energy changes of a bouncing ball, <u>the total amount of kinetic and potential energy</u> must be conserved.
2. The <u>energy due to stretching</u> of a bow can be used to propel an arrow forward.
3. Snow on the side of a mountain has <u>energy due to Earth pulling down on it</u>.
4. The <u>fact that energy cannot be created</u> means that dynamite does not create energy when it explodes.
5. The muscles of a runner transform chemical potential energy into <u>energy of motion</u>.

Chapter 4 Assessment

Checking Concepts

Choose the word or phrase that best answers the question.

1. When energy is transferred from one object to another, what must occur?
- **A)** an explosion
- **B)** a chemical reaction
- **C)** nuclear fusion
- **D)** a change

2. Which has more kinetic energy, a large dog sitting on a sidewalk or a small cat running down the street?
- **A)** the large dog
- **B)** the small cat
- **C)** Both have the same kinetic energy.
- **D)** need more information to answer

3. What energy transformations occur when a lump of clay is dropped?
- **A)** *GPE* → *KE* → thermal energy
- **B)** *KE* → chem *PE* → thermal energy
- **C)** *KE* → *GPE* → thermal energy
- **D)** *GPE* → *KE* → elastic *PE*

4. Suppose a juggler is juggling oranges. At an orange's highest point, what form of energy does it have?
- **A)** mostly potential energy
- **B)** mostly kinetic energy
- **C)** no potential or kinetic energy
- **D)** equal amounts of both

5. The gravitational potential energy of an object depends on which of the following?
- **A)** velocity and height
- **B)** velocity and weight
- **C)** weight and height
- **D)** weight and acceleration

6. Which idea is central to the law of conservation of energy?
- **A)** Friction produces thermal energy.
- **B)** People must conserve energy.
- **C)** The total amount of energy is constant.
- **D)** Energy is the ability to cause change.

7. To what property of an object is kinetic energy directly related?
- **A)** volume
- **B)** height
- **C)** position
- **D)** mass

8. Friction frequently causes some of an object's mechanical energy to be changed to which of the following forms?
- **A)** thermal energy
- **B)** nuclear energy
- **C)** gravitational potential energy
- **D)** chemical potential energy

9. What is the process of breaking apart large atomic nuclei into smaller nuclei called?
- **A)** nuclear fusion
- **B)** nuclear fission
- **C)** atomic fracture
- **D)** transformation

10. Green plants store energy from the Sun in what form?
- **A)** light energy
- **B)** chemical potential energy
- **C)** gravitational potential energy
- **D)** electrical energy

Thinking Critically

11. Briefly describe the energy changes in a swinging pendulum. Explain how energy is conserved, even as a pendulum slows.

12. How is energy transformed when one end of a stretched spring is released?

13. Describe the energy conversions that take place during a roller-coaster ride.

14. Explain why the law of conservation of energy must include mass.

15. A 15-kg bicycle carrying a 50-kg boy is traveling at a speed of 5 m/s. What is the kinetic energy of the bicycle (including the boy)?

Developing Skills

16. Making and Using Tables Make a table that reports the kinetic energy of a 1-kg object moving at various speeds. Compute the kinetic energy at speed increments of 1 m/s, from 0 m/s to 10 m/s.

Energy of a Moving Object

Mass (kg)	Speed (m/s)	KE (J)
1	0	
1	1	
1	2	
1	10	

17. Making and Using Graphs Make a graph to show how kinetic energy changes as speed increases. Using the data from question 16, plot speed on the *x*-axis and kinetic energy on the *y*-axis. Describe the shape of the plotted line. How is the shape of this line different from a straight line?

Performance Assessment

18. Poster Make an educational poster that highlights the law of conservation of energy. Include examples of energy conservation in your daily life.

19. Oral Presentation Research one type of alternative fuel. Find out the advantages and disadvantages of using the fuel. Present your findings to your class.

TECHNOLOGY

Go to the Glencoe Science Web site at **science.glencoe.com** or use the **Glencoe Science CD-ROM** for additional chapter assessment.

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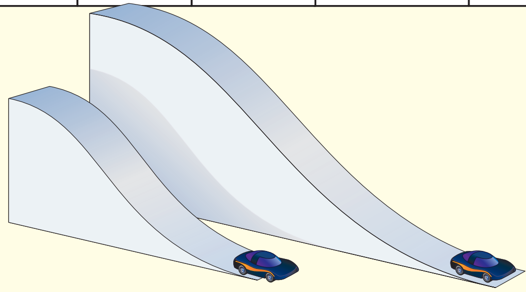
THE PRINCETON REVIEW Test Practice

A team of students conducted an experiment in energy conversion and collected their data in a table.

Trial	Mass of Toy Car (kg)	Distance Traveled (m)	Time to Travel Ramp (s)	Speed (m/s)
1	0.05	1	3.1	0.32
	0.05	2	4.4	0.45
2	0.05	0.5	2.2	0.22
	0.05	1	3.1	0.32



Study the experiment and the table above and answer the following questions.

1. The illustration above shows how these data were collected. Recording which one of the following would improve the experiment?

A) owner of the toy cars
B) weather conditions
C) height of the ramps
D) brand of the toy cars

2. At the beginning of the experiment, a toy car is at rest at the top of a ramp. In this position, what form of energy is stored in the car?

F) kinetic energy
G) fission
H) potential energy
J) mass

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