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

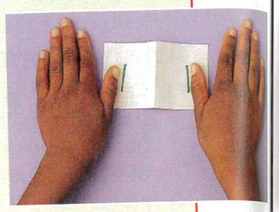
Asking Questions Before you read, preview the red headings and ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Energy Transformations

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

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.

▼ Niagara Falls is more than 50 meters high.

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.

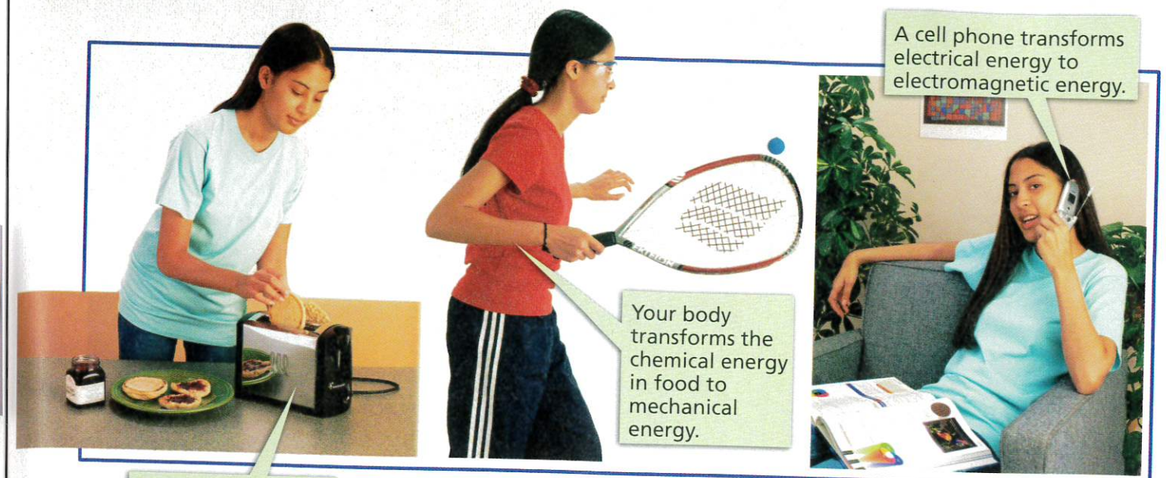


Figure 10
Common Energy Transformations Every day, energy transformations are all around you. Some of these transformations happen inside you! **Observing** *What other energy transformations do you observe every day?*

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?

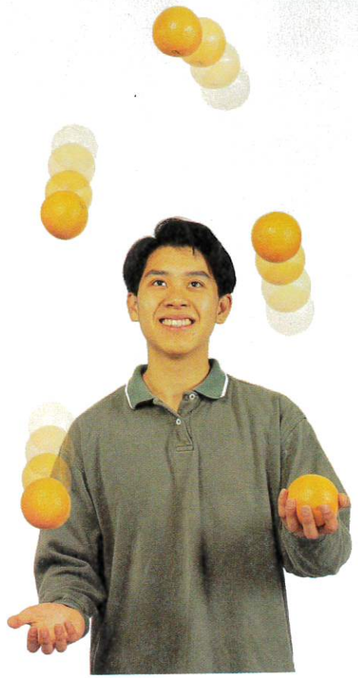


FIGURE 11
Juggling The kinetic energy of an orange thrown into the air becomes gravitational potential energy. Its potential energy becomes kinetic energy as it falls.

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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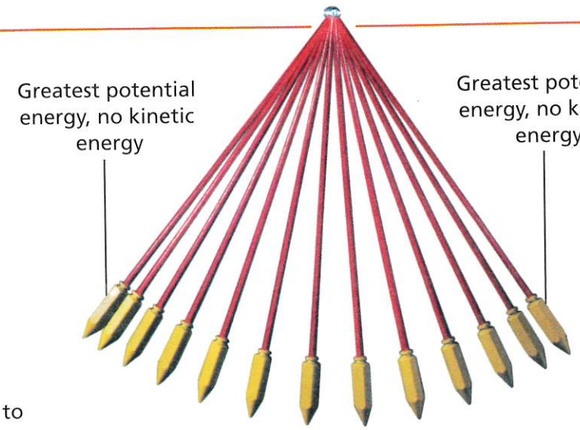

FIGURE 12
Pendulum
A pendulum continuously transforms energy from kinetic to potential energy and back.
Interpreting Diagrams *At what two points is the pendulum's potential energy greatest?*

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?**

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Energy
Video Preview
Video Field Trip
Video Assessment

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.