

Energy and Energy Resources

The Big Idea

Energy can be changed from one form into another form, but energy cannot be created or destroyed.

SECTION

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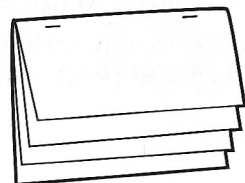
About the PHOTO

Imagine that you're a driver in this race. Your car needs a lot of energy to finish. So, it probably needs a lot of gasoline, right? No, it just needs a lot of sunshine! This car runs on solar energy. Solar energy is one of the many forms of energy. Energy is needed to drive a car, turn on a light bulb, play sports, and walk to school. Energy is always being changed into different forms for different uses.

PRE-READING Activity

FOLDNOTES

Layered Book Before you read the chapter, create the FoldNote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Types of energy," "Energy conversions," "Conservation of energy," and "Energy resources." As you read the chapter, write information you learn about each category under the appropriate tab.



What You Will Learn

- Explain the relationship between energy and work.
- Compare kinetic and potential energy.
- Describe the different forms of energy.

Vocabulary

energy
kinetic energy
potential energy
mechanical energy

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.


What Is Energy?

It's match point. The crowd is silent. The tennis player tosses the ball into the air and then slams it with her racket. The ball flies toward her opponent, who swings her racket at the ball. THWOOSH!! The ball goes into the net, causing it to shake. Game, set, and match!!

The tennis player needs energy to slam the ball with her racket. The ball also must have energy in order to cause the net to shake. Energy is around you all of the time. But what, exactly, is energy?

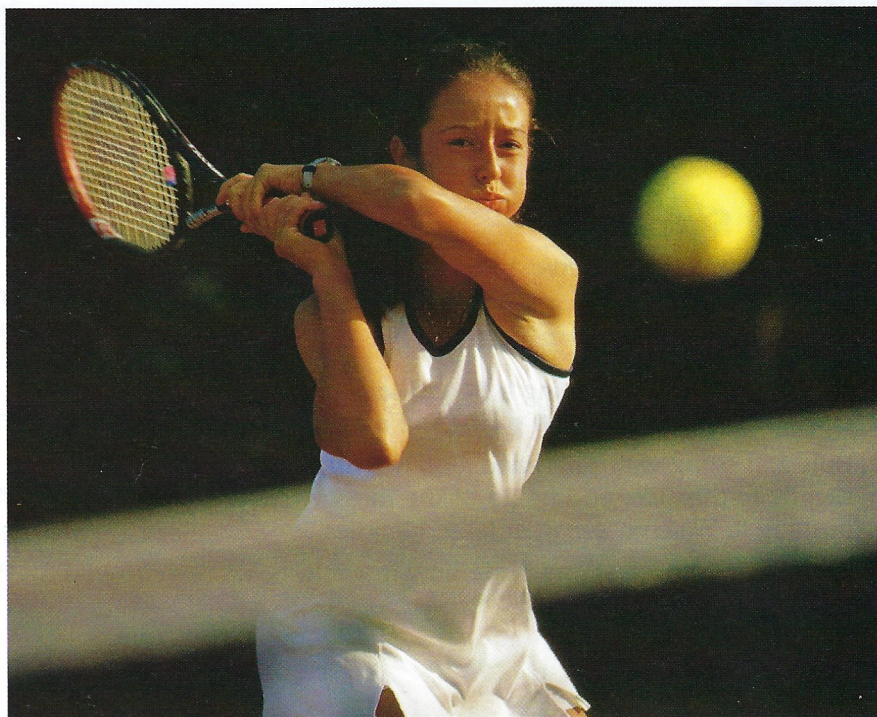
Energy and Work: Working Together

In science, **energy** is the ability to do work. Work is done when a force causes an object to move in the direction of the force. How do energy and work help you play tennis? The tennis player in **Figure 1** does work on her racket by exerting a force on it. The racket does work on the ball, and the ball does work on the net. When one object does work on another, energy is transferred from the first object to the second object. This energy allows the second object to do work. So, work is a transfer of energy. Like work, energy is expressed in units of joules (J).

 **Reading Check** What is energy? (See the Appendix for answers to Reading Checks.)

energy the capacity to do work

Figure 1 The tennis player does work and transfers energy to the racket. With this energy, the racket can then do work on the ball.



Kinetic Energy

In tennis, energy is transferred from the racket to the ball. As it flies over the net, the ball has kinetic (ki NET ik) energy.

Kinetic energy is the energy of motion. All moving objects have kinetic energy. Like all forms of energy, kinetic energy can be used to do work. For example, kinetic energy allows a hammer to do work on a nail, as shown in **Figure 2**.

kinetic energy the energy of an object that is due to the object's motion

Kinetic Energy Depends on Mass and Speed

An object's kinetic energy can be found by the following equation:

$$\text{kinetic energy} = \frac{mv^2}{2}$$

The m stands for the object's mass in kilograms. The v stands for the object's speed. The faster something is moving, the more kinetic energy it has. Also, the greater the mass of a moving object, the greater its kinetic energy is.

A large car has more kinetic energy than a car that has less mass and that is moving at the same speed does. But as you can see from the equation, speed is squared. So speed has a greater effect on kinetic energy than mass does. For this reason, car crashes are much more dangerous at higher speeds than at lower speeds. A moving car has 4 times the kinetic energy of the same car going half the speed! This is because it's going twice the speed of the slower car, and 2 squared is 4.



Figure 2 When you swing a hammer, you give it kinetic energy, which does work on the nail.

MATH FOCUS

Kinetic Energy What is the kinetic energy of a car that has a mass of 1,200 kg and is moving at a speed of 20 m/s?

Step 1: Write the equation for kinetic energy.

$$KE = \frac{mv^2}{2}$$

Step 2: Replace m and v with the measurements given, and solve.

$$KE = \frac{1,200 \text{ kg} \times (20 \text{ m/s})^2}{2}$$

$$KE = \frac{1,200 \text{ kg} \times 400 \text{ m}^2/\text{s}^2}{2}$$

$$KE = \frac{480,000 \text{ kg} \cdot \text{m}^2/\text{s}^2}{2}$$

$$KE = 240,000 \text{ kg} \cdot \text{m}^2/\text{s}^2 = 240,000 \text{ J}$$

Now It's Your Turn

1. What is the kinetic energy of a car that has a mass of 2,400 kg and is moving at 20 m/s? How does this kinetic energy compare to the kinetic energy of the car in the example given at left?
2. What is the kinetic energy of a 4,000 kg elephant that is running at 2 m/s? at 4 m/s? How do the two kinetic energies compare with one another?
3. What is the kinetic energy of a 2,000 kg bus that is moving at 30 m/s?
4. What is the kinetic energy of a 3,000 kg bus that is moving at 20 m/s?

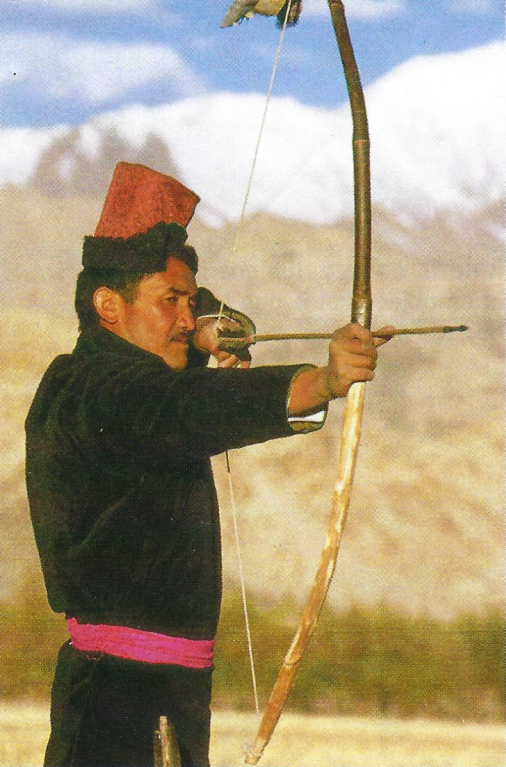


Figure 3 The stored potential energy of the bow and string allows them to do work on the arrow when the string is released.

Potential Energy

Not all energy has to do with motion. **Potential energy** is the energy an object has because of its position. For example, the stretched bow shown in **Figure 3** has potential energy. The bow has energy because work has been done to change its shape. The energy of that work is turned into potential energy.

Gravitational Potential Energy

When you lift an object, you do work on it. You use a force that is against the force of gravity. When you do this, you transfer energy to the object and give the object *gravitational potential energy*. Books on a shelf have gravitational potential energy. So does your backpack after you lift it on to your back. The amount of gravitational potential energy that an object has depends on its weight and its height.

Calculating Gravitational Potential Energy

You can find gravitational potential energy by using the following equation:

$$\text{gravitational potential energy} = \text{weight} \times \text{height}$$

Because weight is expressed in newtons and height in meters, gravitational potential energy is expressed in newton-meters ($\text{N}\cdot\text{m}$), or joules (J).

Recall that $\text{work} = \text{force} \times \text{distance}$. Weight is the amount of force that you must use on an object to lift it, and height is a distance. So, gravitational potential energy is equal to the amount of work done on the object to lift it to a certain height. Or, you can think of gravitational potential energy as being equal to the work that would be done by the object if it were dropped from that height.

MATH FOCUS

Gravitational Potential Energy What is the gravitational potential energy of a book with a weight of 13 N at a height of 1.5 m off the ground?

Step 1: Write the equation for gravitational potential energy (GPE).

$$GPE = \text{weight} \times \text{height}$$

Step 2: Replace the weight and height with the measurements given in the problem, and solve.

$$GPE = 13 \text{ N} \times 1.5 \text{ m}$$

$$GPE = 19.5 \text{ N}\cdot\text{m} = 19.5 \text{ J}$$

Now It's Your Turn

1. What is the gravitational potential energy of a cat that weighs 40 N standing on a table that is 0.8 m above the ground?
2. What is the gravitational potential energy of a diver who weighs 500 N standing on a platform that is 10 m off the ground?
3. What is the gravitational potential energy of a diver who weighs 600 N standing on a platform that is 8 m off the ground?

Height Above What?

When you want to find out an object's gravitational potential energy, the "ground" that you measure the object's height from depends on where it is. For example, what if you want to measure the gravitational potential energy of an egg sitting on the kitchen counter? In this case, you would measure the egg's height from the floor. But if you were holding the egg over a balcony several stories from the ground, you would measure the egg's height from the ground! You can see that gravitational potential energy depends on your point of view. So, the height you use in calculating gravitational potential energy is a measure of how far an object has to fall.

Mechanical Energy

How would you describe the energy of the juggler's pins in **Figure 4**? To describe their total energy, you would state their mechanical energy. **Mechanical energy** is the total energy of motion and position of an object. Both potential energy and kinetic energy are kinds of mechanical energy. Mechanical energy can be all potential energy, all kinetic energy, or some of each. You can use the following equation to find mechanical energy:

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

Reading Check What two kinds of energy can make up the mechanical energy of an object?

Mechanical Energy in a Juggler's Pin

The mechanical energy of an object remains the same unless it transfers some of its energy to another object. But even if the mechanical energy of an object stays the same, the potential energy or kinetic energy it has can increase or decrease.

Look at **Figure 4**. While the juggler is moving the pin with his hand, he is doing work on the pin to give it kinetic energy. But as soon as the pin leaves his hand, the pin's kinetic energy starts changing into potential energy. How can you tell that the kinetic energy is decreasing? The pin slows down as it moves upwards. Eventually, all of the pin's kinetic energy turns into potential energy, and it stops moving upward.

As the pin starts to fall back down again, its potential energy starts changing back into kinetic energy. More and more of its potential energy turns into kinetic energy. You can tell because the pin speeds up as it falls towards the ground.

potential energy the energy that an object has because of the position, shape, or condition of the object

mechanical energy the amount of work an object can do because of the object's kinetic and potential energies

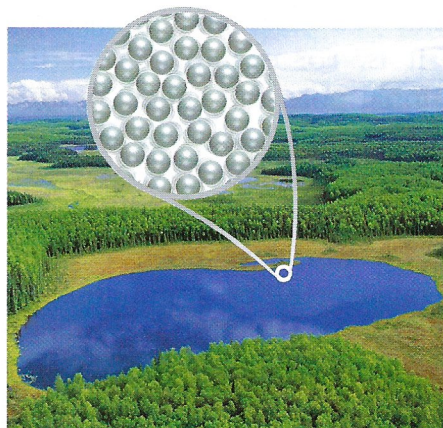
Figure 4 As a pin is juggled, its mechanical energy is the sum of its potential energy and its kinetic energy at any point.



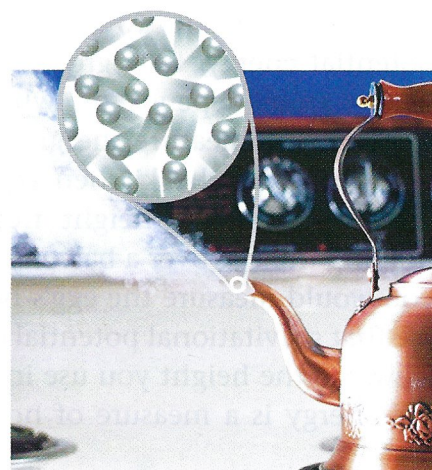
Figure 5 Thermal Energy in Water



The particles in an ice cube vibrate in fixed positions and do not have a lot of kinetic energy.



The particles of water in a lake can move more freely and have more kinetic energy than water particles in ice do.



The particles of water in steam move rapidly, so they have more energy than the particles in liquid water do.

Other Forms of Energy

Energy can come in a number of forms besides mechanical energy. These forms of energy include thermal, chemical, electrical, sound, light, and nuclear energy. As you read the next few pages, you will learn what these different forms of energy have to do with kinetic and potential energy.

Thermal Energy

All matter is made of particles that are always in random motion. Because the particles are in motion, they have kinetic energy. *Thermal energy* is all of the kinetic energy due to random motion of the particles that make up an object.

As you can see in **Figure 5**, particles move faster at higher temperatures than at lower temperatures. The faster the particles move, the greater their kinetic energy and the greater the object's thermal energy. Thermal energy also depends on the number of particles. Water in the form of steam has a higher temperature than water in a lake does. But the lake has more thermal energy because the lake has more water particles.

Chemical Energy

Where does the energy in food come from? Food is made of chemical compounds. When compounds such as sugar form, work is done to join the different atoms together. *Chemical energy* is the energy of a compound that changes as its atoms are rearranged. Chemical energy is a form of potential energy because it depends on the position and arrangement of the atoms in a compound.

INTERNET ACTIVITY

For another activity related to this chapter, go to go.hrw.com and type in the keyword **HP5ENGW**.

Quick Lab

Hear That Energy!

1. Make a simple drum by covering the open end of an **empty coffee can** with **wax paper**. Secure the wax paper with a **rubber band**.
2. Using the eraser end of a **pencil**, tap lightly on the wax paper. Describe how the paper responds. What do you hear?
3. Repeat step 2, but tap the paper a bit harder. Compare your results with those of step 2.
4. Cover half of the wax paper with one hand. Now, tap the paper. What happened? How can you describe sound energy as a form of mechanical energy?

Electrical Energy

The electrical outlets in your home allow you to use electrical energy. *Electrical energy* is the energy of moving electrons. Electrons are the negatively charged particles of atoms.

Suppose you plug an electrical device, such as the amplifier shown in **Figure 6**, into an outlet and turn it on. The electrons in the wires will transfer energy to different parts inside the amplifier. The electrical energy of moving electrons is used to do work that makes the sound that you hear from the amplifier.

The electrical energy used in your home comes from power plants. Huge generators turn magnets inside loops of wire. The changing position of a magnet makes electrical energy run through the wire. This electrical energy can be thought of as potential energy that is used when you plug in an electrical appliance and use it.

Sound Energy

Figure 7 shows how a vibrating object transmits energy through the air around it. Sound energy is caused by an object's vibrations. When you stretch a guitar string, the string stores potential energy. When you let the string go, this potential energy is turned into kinetic energy, which makes the string vibrate. The string also transmits some of this kinetic energy to the air around it. The air particles also vibrate, and transmit this energy to your ear. When the sound energy reaches your ear, you hear the sound of the guitar.

✓ Reading Check What does sound energy consist of?

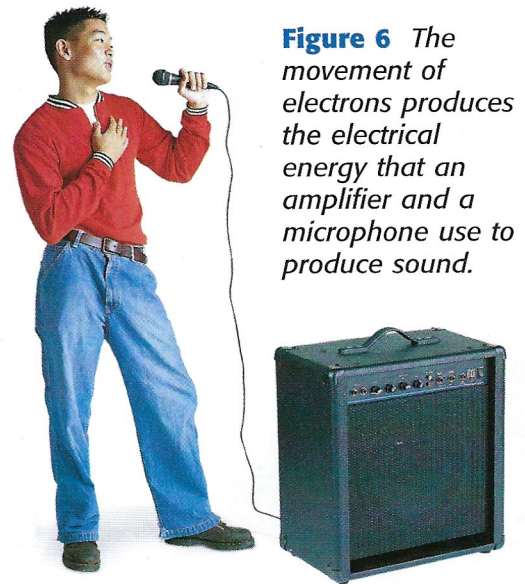
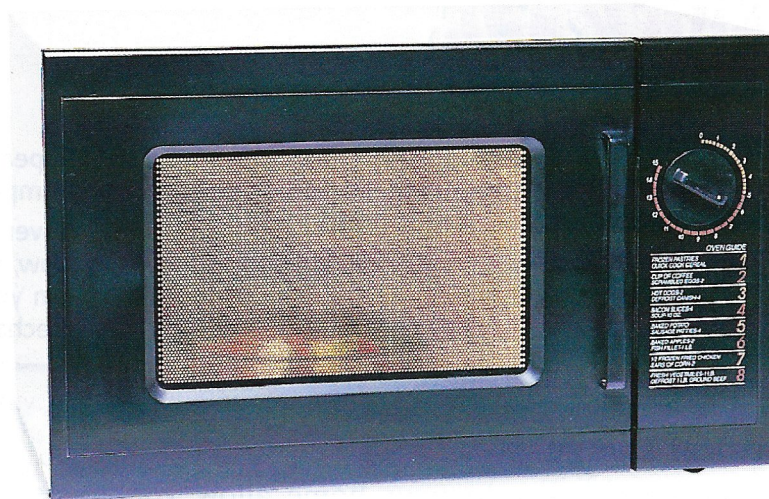


Figure 6 The movement of electrons produces the electrical energy that an amplifier and a microphone use to produce sound.



Figure 7 As the guitar strings vibrate, they cause particles in the air to vibrate. These vibrations transmit sound energy.

Figure 8 The energy used to cook food in a microwave is a form of light energy.



Light Energy

Light allows you to see, but did you know that not all light can be seen? **Figure 8** shows a type of light that we use but can't see. *Light energy* is produced by the vibrations of electrically charged particles. Like sound vibrations, light vibrations cause energy to be transmitted. But the vibrations that transmit light energy don't need to be carried through matter. In fact, light energy can move through a vacuum (an area where there is no matter).

Nuclear Energy

There is a form of energy that comes from a tiny amount of matter. It is used to generate electrical energy, and it gives the sun its energy. It is *nuclear* (NOO klee uhr) *energy*, the energy that comes from changes in the nucleus (NOO klee uhs) of an atom.

Atoms store a lot of potential energy because of the positions of the particles in the nucleus of the atoms. When two or more small nuclei (NOO klee ie) join together, or when the nucleus of a large atom splits apart, energy is given off.

The energy given off by the sun comes from nuclear energy. In the sun, shown in **Figure 9**, hydrogen nuclei join together to make a larger helium nucleus. This reaction, known as *fusion*, gives off a huge amount of energy. The sun's light and heat come from these reactions.

When a nucleus of a heavy element such as uranium is split apart, the potential energy in the nucleus is given off. This kind of nuclear energy is called *fission*. Fission is used to generate electrical energy at nuclear power plants.

 **Reading Check** Where does nuclear energy come from?

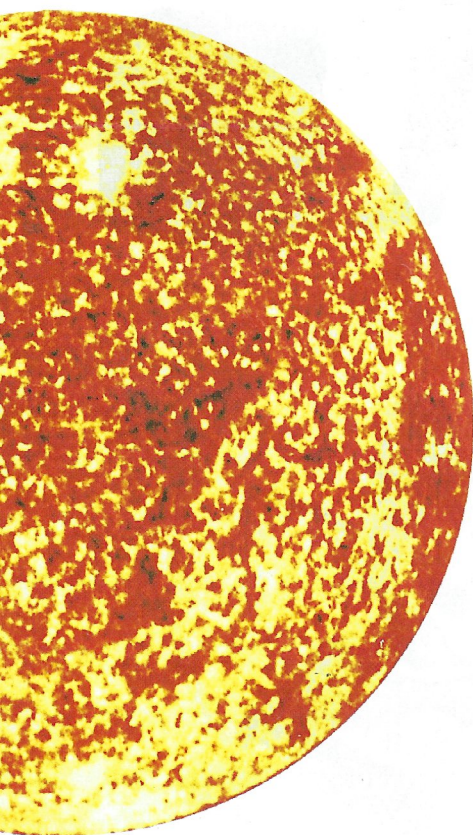


Figure 9 Without the nuclear energy from the sun, life on Earth would not be possible.

SECTION Review

Summary

- Energy is the ability to do work, and work equals the transfer of energy. Energy and work are expressed in units of joules (J).
- Kinetic energy is energy of motion and depends on speed and mass.
- Potential energy is energy of position. Gravitational potential energy depends on weight and height.
- Mechanical energy is the sum of kinetic energy and potential energy.
- Thermal energy and sound energy can be considered forms of kinetic energy.
- Chemical energy, electrical energy, and nuclear energy can be considered forms of potential energy.

Using Key Terms

1. In your own words, write a definition for the term *energy*.
2. Use the following terms in the same sentence: *kinetic energy*, *potential energy*, and *mechanical energy*.

Understanding Key Ideas

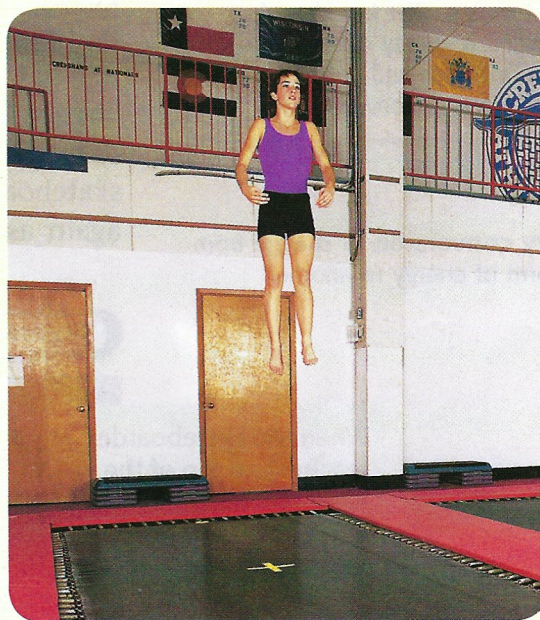
3. What determines an object's thermal energy?
 - a. the motion of its particles
 - b. its size
 - c. its potential energy
 - d. its mechanical energy
4. How are energy and work related?
5. What two factors determine gravitational potential energy?
6. Describe why chemical energy is a form of potential energy.

Critical Thinking

7. **Identifying Relationships** When you hit a nail into a board by using a hammer, the head of the nail gets warm. In terms of kinetic and thermal energy, describe why you think the nail head gets warm.
8. **Applying Concepts** Explain why a high-speed collision may cause more damage to vehicles than a low-speed collision does.

Interpreting Graphics

9. Which part of mechanical energy does the girl in the picture below have the most of?



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For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is Energy? ; Forms of Energy

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