KEY CONCEPT

4.3 Power is the rate at which work is done.

BEFORE, you learned

- Mechanical energy is a combination of kinetic energy and potential energy
- Mechanical energy can be calculated
- Work transfers energy

NOW, you will learn

- How power is related to work and time
- How power is related to energy and time
- About common uses of power

VOCABULARY

power p. 130
watt p. 131
horsepower p. 132

EXPLORE Power

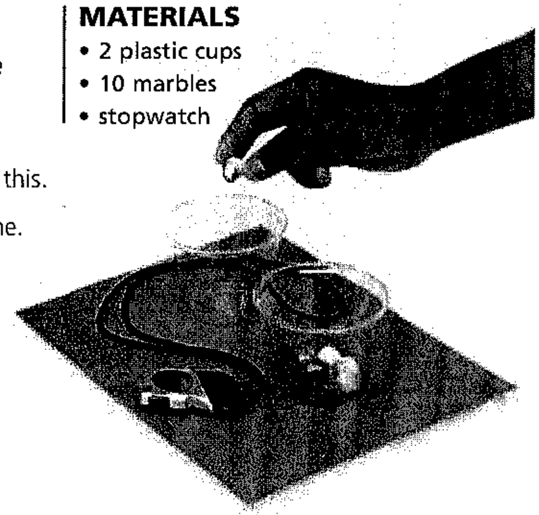
How does time affect work?

PROCEDURE

1. Place the cups side by side. Put all of the marbles in one cup.
2. Place each marble, one by one, into the other cup. Time how long it takes to do this.
3. Set the timer for half that amount of time. Then repeat step 2 in that time.

MATERIALS

- 2 plastic cups
- 10 marbles
- stopwatch



WHAT DO YOU THINK?

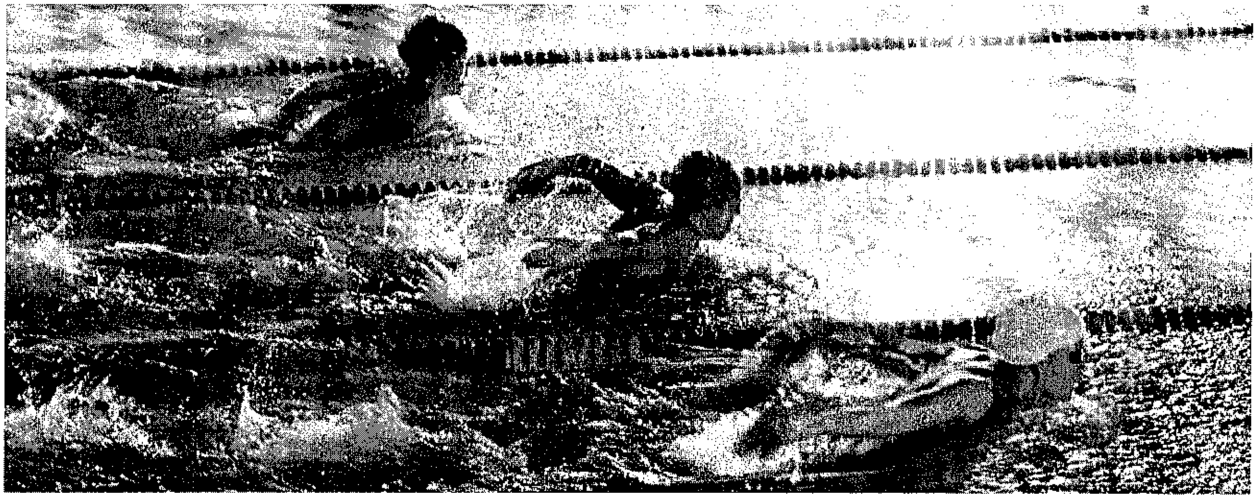
- Did you do more work the first time or the second time? Why?
- What differences did you notice between the two tries?

Power can be calculated from work and time.

VOCABULARY
Use a vocabulary strategy to help you remember the meaning of *power*.

If you lift a book one meter, you do the same amount of work whether you lift the book quickly or slowly. However, when you lift the book quickly, you increase your **power**—the rate at which you do work. A cook increases his power when he beats eggs rapidly instead of stirring them slowly. A runner increases her power when she breaks into a sprint to reach the finish line.

The word *power* has different common meanings. It is used to mean a source of energy, as in a power plant, or strength, as in a powerful engine. When you talk about a powerful swimmer, for example, you would probably say that the swimmer is very strong or very fast. If you use the scientific definition of power, you would instead say that a powerful swimmer is one who does the work of moving herself through the water in a short time.



Each of the swimmers shown in the photograph above is doing work—that is, she is using a certain force to move a certain distance. It takes time to cover that distance. The power a swimmer uses depends on the force, the distance, and the time it takes to cover that distance. The more force the swimmer uses, the more power she has. Also, the faster she goes, the more power she has because she is covering the same distance in a shorter time. Swimmers often increase their speed toward the end of a race, which increases their power, making it possible for them to reach the end of the pool in less time.

CHECK YOUR READING Summarize in your own words the difference between work and power.

Calculating Power from Work

You know that a given amount of work can be done by a slow-moving swimmer over a long period of time or by a fast-moving swimmer in a short time. Likewise, a given amount of work can be done by a low-powered motor over a long period of time or by a high-powered motor in a short time.

Because power is a measurement of how much work is done in a given time, power can be calculated based on work and time. To find power, divide the amount of work by the time it takes to do the work.

$$\text{Power} = \frac{\text{Work}}{\text{time}} \qquad P = \frac{W}{t}$$

READING TIP
W (in italicized type) is the letter that represents the variable *Work*. W, not italicized, is the abbreviation for watt.

Remember that work is measured in joules. Power is often measured in joules of work per second. The unit of measurement for power is the **watt** (W). One watt is equal to one joule of work done in one second. If an object does a large amount of work, its power is usually measured in units of 1000 watts, or kilowatts.

RESOURCE CENTER
CLASSZONE.COM
Find out more about power.

Calculating Power from Work

Sample Problem

An Antarctic explorer uses 6000 J of work to pull his sled for 60 s. What power does he need?

What do you know? Work = 6000 J, time = 60 s

What do you want to find out? Power

Write the formula: $P = \frac{W}{t}$

Substitute into the formula: $P = \frac{6000\ \text{J}}{60\ \text{s}}$

Calculate and simplify: P = 100 J/s = 100 W

Check that your units agree: $\frac{\text{J}}{\text{s}} = \text{W}$

Unit of power is W. Units agree.

Answer: P = 100 W

Practice the Math

1. If a conveyor belt uses 10 J to move a piece of candy a distance of 3 m in 20 s, what is the conveyor belt's power?
2. An elevator uses a force of 1710 N to lift 3 people up 1 floor. Each floor is 4 m high. The elevator takes 8 s to lift the 3 people up 2 floors. What is the elevator's power?

Horsepower

James Watt, the Scottish engineer for whom the watt is named, improved the power of the steam engine in the mid-1700s. Watt also developed a unit of measurement for power called the horsepower. **Horsepower** is based on what it sounds like—the amount of work a horse can do in a minute. In Watt's time, people used horses to do many different types of work. For example, horses were used on farms to pull plows and wagons.

Both the horse and the tractor use power to pull objects around a farm.

Watt wanted to explain to people how powerful his steam engine was compared with horses. After observing several horses doing work, Watt concluded that an average horse could move 150 pounds a distance of 220 feet in 1 minute. Watt called this amount of power 1 horsepower. A single horsepower is equal to 745 watts. Therefore, a horsepower is a much larger unit of measurement than a watt.

Today horsepower is used primarily in connection with engines and motors. For example, you may see a car advertised as having a 150-horsepower engine. The power of a motorboat, lawn mower, tractor, or motorcycle engine is also referred to as horsepower.

INVESTIGATE Power

How much power do you have?

PROCEDURE

1. Measure a length of 5 meters on the floor. Mark the beginning and the end of the 5 meters with masking tape.
2. Attach the object to the spring scale with a piece of string. Slowly pull the object across the floor using a steady amount of force. Record the force and the time it takes you to pull the object.

WHAT DO YOU THINK?

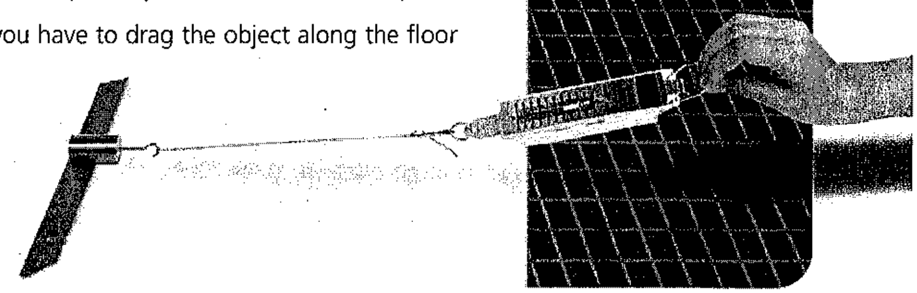
- How much power did you use to pull the object 5 meters?
- How do you think you could increase the power you used? decrease the power?

CHALLENGE How quickly would you have to drag the object along the floor to produce 40 watts of power?

SKILL FOCUS
Measuring

MATERIALS
- meter stick
- masking tape
- 100 g object
- spring scale
- string
- stopwatch

TIME
15 minutes



Power can be calculated from energy and time.

Sometimes you may know that energy is being transferred, but you cannot directly measure the work done by the forces involved. For example, you know that a television uses power. But there is no way to measure all the work every part of the television does in terms of forces and distance. Because work measures the transfer of energy, you can also think of power as the amount of energy transferred over a period of time.

Calculating Power from Energy

When you turn on a television, it starts using energy. Each second the television is on, a certain amount of electrical energy is transferred from a local power plant to your television. If you measure how much energy your television uses during a given time period, you can find out how much power it needs by using the following formula:

$$\text{Power} = \frac{\text{Energy}}{\text{time}} \qquad P = \frac{E}{t}$$

This formula should look familiar to you because it is very similar to the formula used to calculate power from work.

The photograph shows Hong Kong, China, at night. Every second, the city uses more than 4 billion joules of electrical energy!

You can think about power as any kind of transfer of energy in a certain amount of time. It is useful to think of power in this way if you cannot directly figure out the work used to transfer the energy. Power calculated from transferred energy is also measured in joules per second, or watts.

You have probably heard the term *watt* used in connection with light bulbs. A 60-watt light bulb requires 60 joules of energy every second to shine at its rated brightness.

CHECK YOUR READING In what situations is it useful to think of power as the transfer of energy in a certain amount of time?

Calculating Power from Energy

Sample Problem

A light bulb used 600 J of energy in 6 s. What is the power of the light bulb?

What do you know? Energy = 600 J, time = 6 s

What do you want to find out? Power

Write the formula: $P = \frac{E}{t}$

Substitute into the formula: $P = \frac{600\ \text{J}}{6\ \text{s}}$

Calculate and simplify: $P = 100$ J/s

Check that your units agree: Unit is J/s. Unit for power is W, which is also J/s. Units agree.

Answer: $P = 100$ W

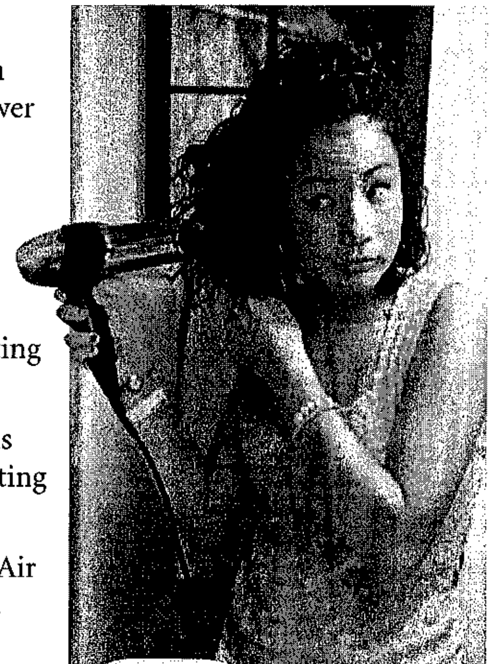
Practice the Math

1. A laptop computer uses 100 J every 2 seconds. How much power is needed to run the computer?
2. The power needed to pump blood through your body is about 1.1 W. How much energy does your body use when pumping blood for 10 seconds?

REMINDER

Remember that energy and work are both measured in joules.

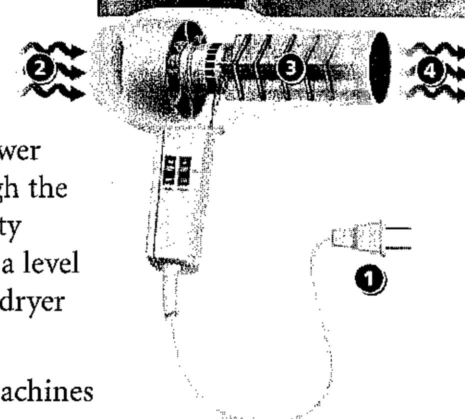
Everyday Power



Many appliances in your home rely on electricity for energy. Each appliance requires a certain number of joules per second, the power it needs to run properly. An electric hair dryer uses energy. For example, a 600-watt hair dryer needs 600 joules per second. The wattage of the hair dryer indicates how much energy per second it needs to operate.

The dryer works by speeding up the evaporation of water on the surface of hair. It needs only two main parts to do this: a heating coil and a fan turned by a motor.

1. When the hair dryer is plugged into an outlet and the switch is turned on, electrical energy moves electrons in the wires, creating a current.
2. This current runs an electric motor that turns the fan blades. Air is drawn into the hair dryer through small holes in the casing. The turning fan blades push the air over the coil.
3. The current also makes the heating coil become hot.
4. The fan pushes heated air out of the dryer.



Most hair dryers have high and low settings. At the high power setting, the temperature is increased, more air is pushed through the dryer, and the dryer does its work faster. Some dryers have safety switches that shut off the motor when the temperature rises to a level that could burn your scalp. Insulation keeps the outside of the dryer from becoming hot to the touch.

Many other appliances, from air conditioners to washing machines to blenders, need electrical energy to do their work. Take a look around you at all the appliances that help you during a typical day.

4.3 Review

KEY CONCEPTS

1. How is power related to work?
2. Name two units used for power, and give examples of when each unit might be used.
3. What do you need to know to calculate how much energy a light bulb uses?

CRITICAL THINKING

4. **Apply** Discuss different ways in which a swimmer can increase her power.
5. **Calculate** Which takes more power: using 15 N to lift a ball 2 m in 5 seconds or using 100 N to push a box 2 m in 1 minute?

CHALLENGE

6. **Analyze** A friend tells you that you can calculate power by using a different formula from the one given in this book. The formula your friend gives you is as follows:
   Power = force • speed
   Do you think this is a valid formula for power? Explain.