20

The Energy of Waves

The Big Idea

Waves transfer energy, have describable properties, and interact in predictable ways.

SECTION

About the PHOTO

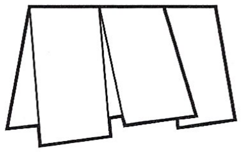
A surfer takes advantage of a wave's energy to catch an exciting ride. The ocean wave that this surfer is riding is just one type of wave. You are probably familiar with water waves. But did you know that light, sound, and even earthquakes are waves? From music to television, waves play an important role in your life every day.

PRE-READING ACTIVITY

FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Three-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with "The nature of waves," "Properties of waves," and "Wave interactions." As you read the chapter, write information you learn about each category under the appropriate flap.



SECTION 1

The Nature of Waves

Imagine that your family has just returned home from a day at the beach. You had fun playing in the ocean under a hot sun. You put some cold pizza in the microwave for dinner, and you turn on the radio. Just then, the phone rings. It's your friend calling to ask about homework.

In the events described above, how many different waves were present? Believe it or not, there were at least five! Can you name them? Here's a hint: A **wave** is any disturbance that transmits energy through matter or empty space. Okay, here are the answers: water waves in the ocean; light waves from the sun; microwaves inside the microwave oven; radio waves transmitted to the radio; and sound waves from the radio, telephone, and voices. Don't worry if you didn't get very many. You will be able to name them all after you read this section.

Reading Check **What do all waves have in common?** (*See the Appendix for answers to Reading Checks.*)

What You Will Learn

- Describe how waves transfer energy without transferring matter.
- Distinguish between waves that require a medium and waves that do not.
- Explain the difference between transverse and longitudinal waves.

Vocabulary

wave
medium
transverse wave
longitudinal wave

READING STRATEGY

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

wave a periodic disturbance in a solid, liquid, or gas as energy is transmitted through a medium

Wave Energy

Energy can be carried away from its source by a wave. You can observe an example of a wave if you drop a rock in a pond. Waves from the rock's splash carry energy away from the splash. However, the material through which the wave travels does not move with the energy. Look at **Figure 1.** Can you move a leaf on a pond if you are standing on the shore? You can make the leaf bob up and down by making waves that carry enough energy through the water. But you would not make the leaf move in the same direction as the wave.

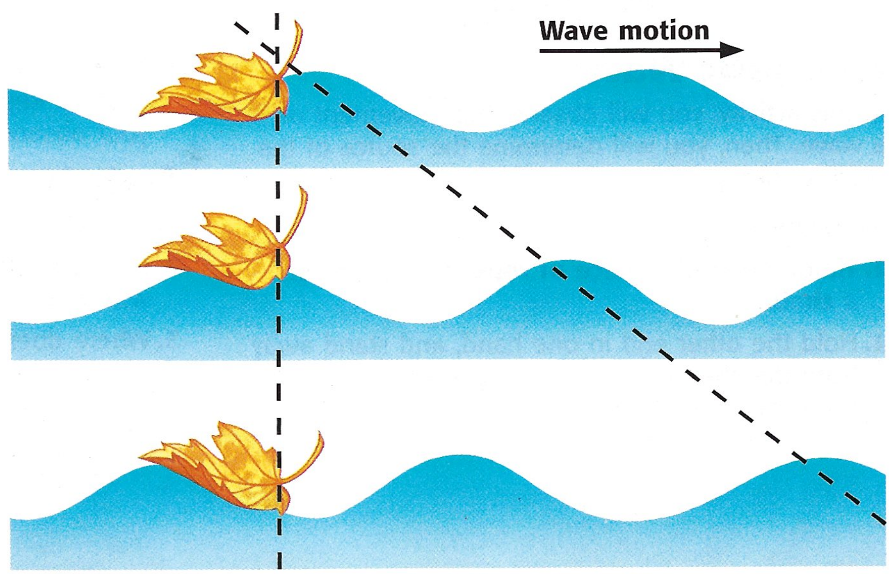


Figure 1 *Waves on a pond move toward the shore, but the water and the leaf floating on the surface only bob up and down.*

Waves and Work

As a wave travels, it does work on everything in its path. The waves in a pond do work on the water to make it move up and down. The waves also do work on anything floating on the water's surface. For example, boats and ducks bob up and down with waves. The fact that these objects move tells you that the waves are transferring energy.

Energy Transfer Through a Medium

Most waves transfer energy by the vibration of particles in a medium. A **medium** is a substance through which a wave can travel. A medium can be a solid, a liquid, or a gas. The plural of *medium* is *media*.

When a particle vibrates (moves back and forth, as in **Figure 2**), it can pass its energy to a particle next to it. The second particle will vibrate like the first particle does. In this way, energy is transmitted through a medium.

Sound waves need a medium. Sound energy travels by the vibration of particles in liquids, solids, and gases. If there are no particles to vibrate, no sound is possible. If you put an alarm clock inside a jar and remove all the air from the jar to create a vacuum, you will not be able to hear the alarm.

Other waves that need a medium include ocean waves, which move through water, and waves that are carried on guitar and cello strings when they vibrate. Waves that need a medium are called *mechanical waves*. **Figure 3** shows the effect of a mechanical wave in Earth's crust: an earthquake.

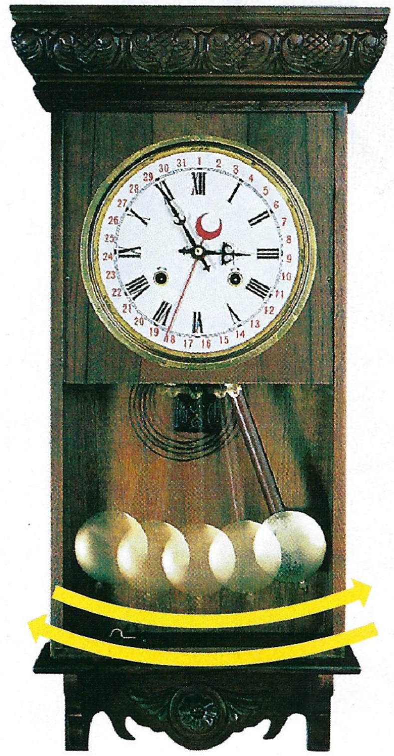


Figure 2 *A vibration is one complete back-and-forth motion of an object.*

medium a physical environment in which phenomena occur

Figure 3 *Earthquakes cause seismic waves to travel through Earth's crust. The energy they carry can be very destructive to anything on the ground.*

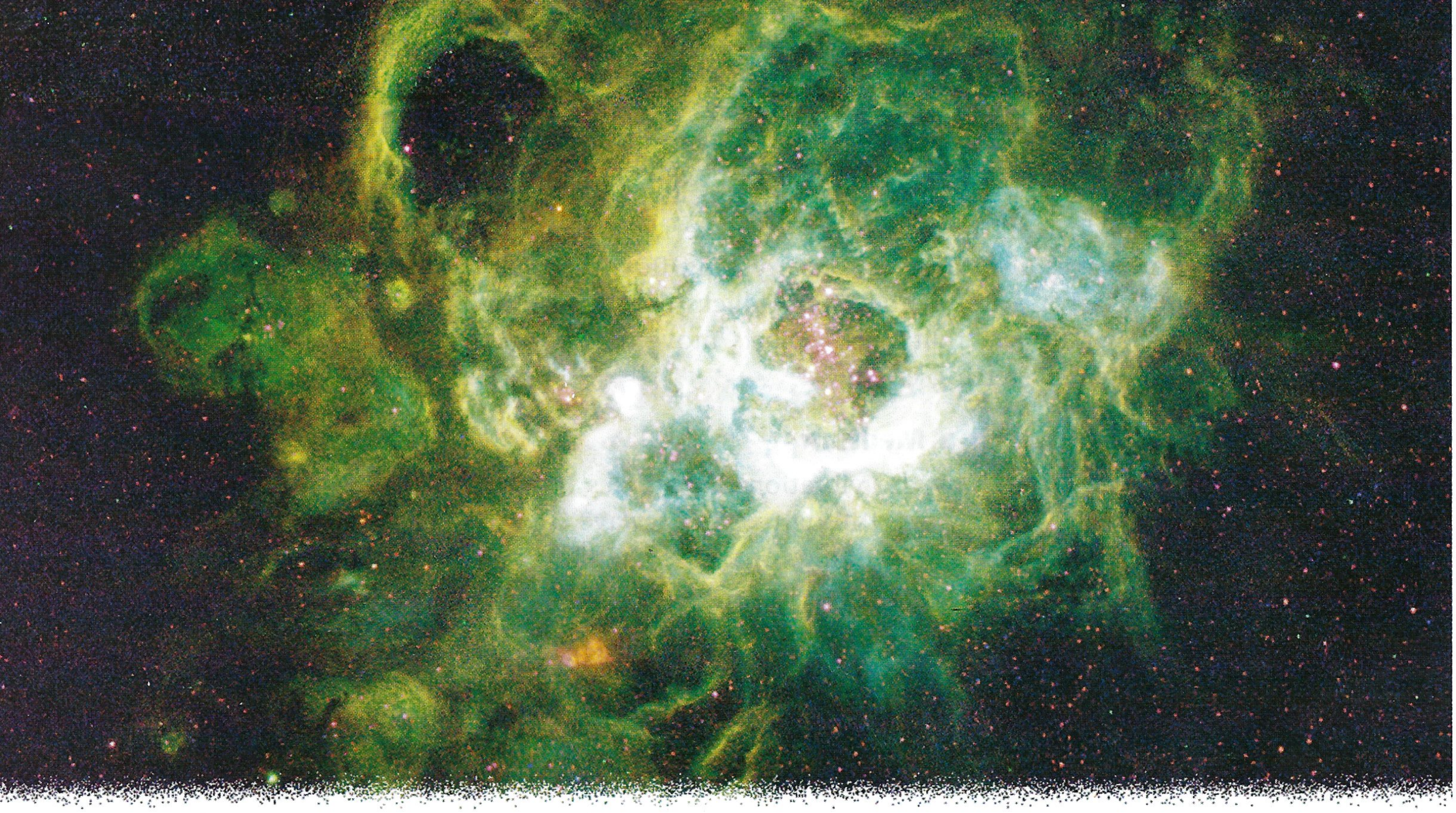


Figure 4 *Light waves are electromagnetic waves, which do not need a medium. Light waves from the Crab nebula, shown here, travel through the vacuum of space billions of miles to Earth, where they can be detected with a telescope.*

Energy Transfer Without a Medium

Some waves can transfer energy without going through a medium. Visible light is one example. Other examples include microwaves made by microwave ovens, TV and radio signals, and X rays used by dentists and doctors. These waves are *electromagnetic waves.*

Although electromagnetic waves do not need a medium, they can go through matter, such as air, water, and glass. The energy that reaches Earth from the sun comes through electromagnetic waves, which go through space. As shown in **Figure 4,** you can see light from stars because electromagnetic waves travel through space to Earth. Light is an electromagnetic wave that your eyes can see.

Reading Check How do electromagnetic waves differ from mechanical waves?

CONNECTION TO Astronomy

Light Speed Light waves from stars and galaxies travel great distances that are best expressed in light-years. A light-year is the distance a ray of light can travel in one year. Some of the light waves from these stars have traveled billions of light-years before reaching Earth. Do the following calculation in your **science journal:** If light travels at a speed of 300,000,000 m/s, what distance is a light-minute? (Hint: There are 60 s in a minute.) ACTIVITY

Types of Waves

All waves transfer energy by repeated vibrations. However, waves can differ in many ways. Waves can be classified based on the direction in which the particles of the medium vibrate compared with the direction in which the waves move. The two main types of waves are *transverse waves* and *longitudinal* (LAHN juh TOOD'n uhl) *waves*. Sometimes, a transverse wave and a longitudinal wave can combine to form another kind of wave called a *surface wave*.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5WAVW.**

Transverse Waves

Waves in which the particles vibrate in an up-and-down motion are called **transverse waves.** *Transverse* means "moving across." The particles in this kind of wave move across, or perpendicularly to, the direction that the wave is going. To be *perpendicular* means to be "at right angles."

transverse wave a wave in which the particles of the medium move perpendicularly to the direction the wave is traveling

A wave moving on a rope is an example of a transverse wave. In **Figure 5,** you can see that the points along the rope vibrate perpendicularly to the direction the wave is going. The highest point of a transverse wave is called a *crest,* and the lowest point between each crest is called a *trough* (TRAWF). Although electromagnetic waves do not travel by vibrating particles in a medium, all electromagnetic waves are considered transverse waves. The reason is that the waves are made of vibrations that are perpendicular to the direction of motion.

Figure 5 Motion of a Transverse Wave

A wave on a rope is a transverse wave because the particles of the medium vibrate perpendicularly to the direction the wave moves.

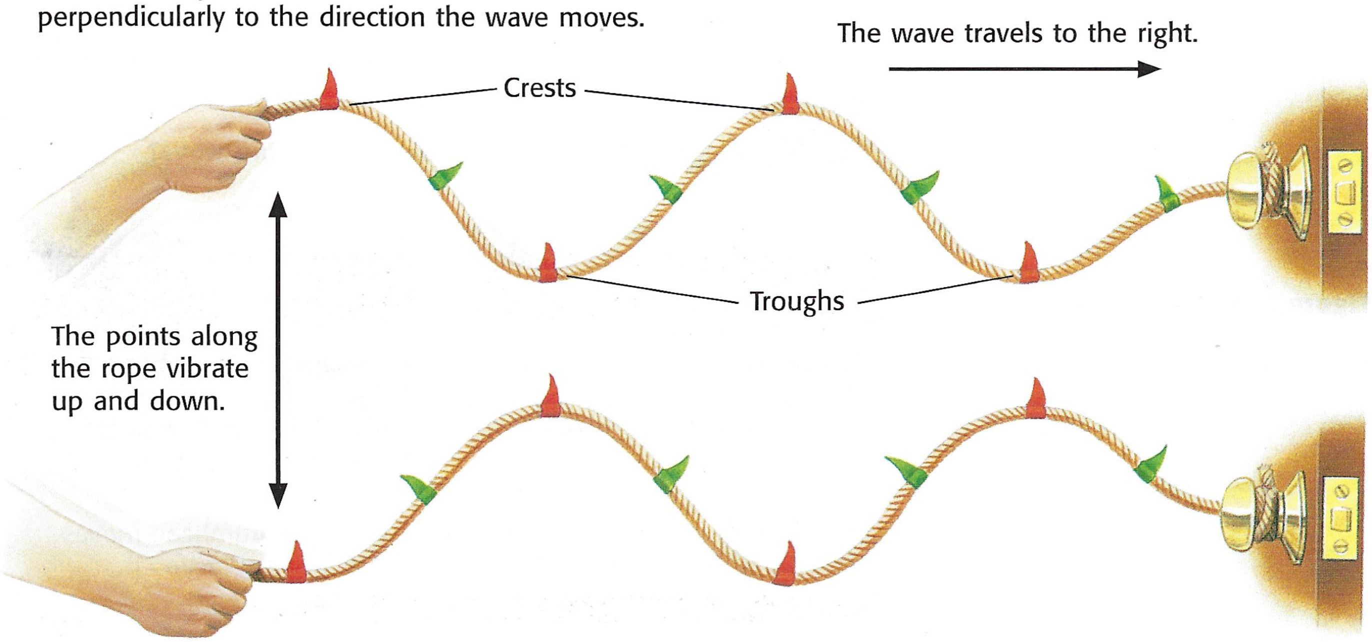
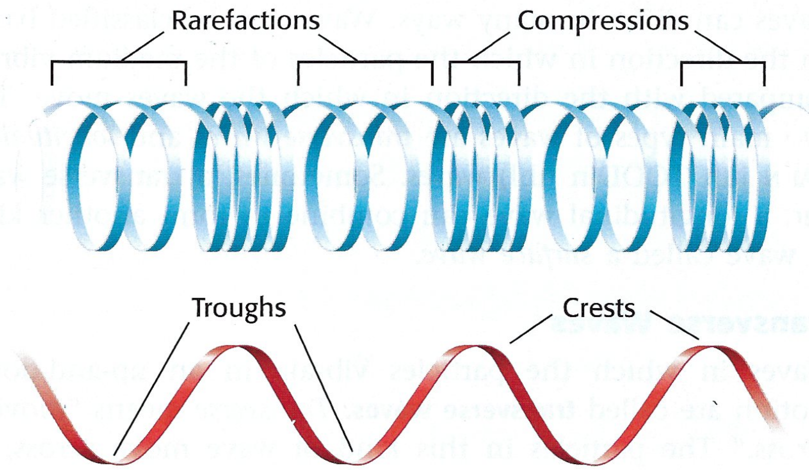


Figure 6 Comparing Longitudinal and Transverse Waves

Pushing a spring back and forth creates a longitudinal wave, much the same way that shaking a rope up and down creates a transverse wave.



Longitudinal Waves

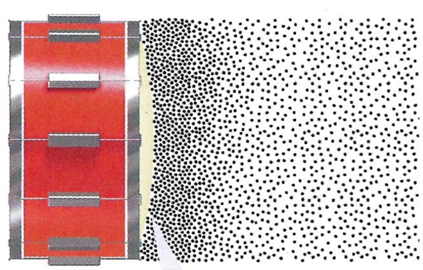
longitudinal wave a wave in which the particles of the medium vibrate parallel to the direction of wave motion

In a **longitudinal wave,** the particles of the medium vibrate back and forth along the path that the wave moves. You can make a longitudinal wave on a spring. When you push on the end of the spring, the coils of the spring crowd together. A part of a longitudinal wave where the particles are crowded together is called a *compression*. When you pull back on the end of the spring, the coils are pulled apart. A part where the particles are spread apart is a *rarefaction* (RER uh FAK shuhn). Compressions and rarefactions are like the crests and troughs of a transverse wave, as shown in **Figure 6.**

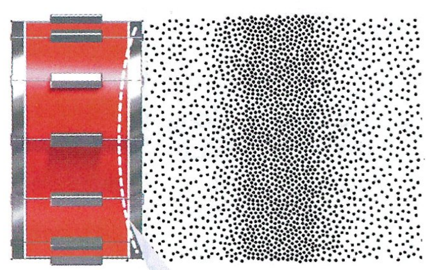
Sound Waves

A sound wave is an example of a longitudinal wave. Sound waves travel by compressions and rarefactions of air particles. **Figure 7** shows how a vibrating drum forms compressions and rarefactions in the air around it.

Reading Check What kind of wave is a sound wave?



When the drumhead moves out after being hit, a compression is created in the air particles.



When the drumhead moves back in, a rarefaction is created.

Figure 7 *Sound energy is carried away from a drum by a longitudinal wave through the air.*

Combinations of Waves

When waves form at or near the boundary between two media, a transverse wave and a longitudinal wave can combine to form a *surface wave*. An example is shown in **Figure 8.** Surface waves look like transverse waves, but the particles of the medium in a surface wave move in circles rather than up and down. The particles move forward at the crest of each wave and move backward at the trough.

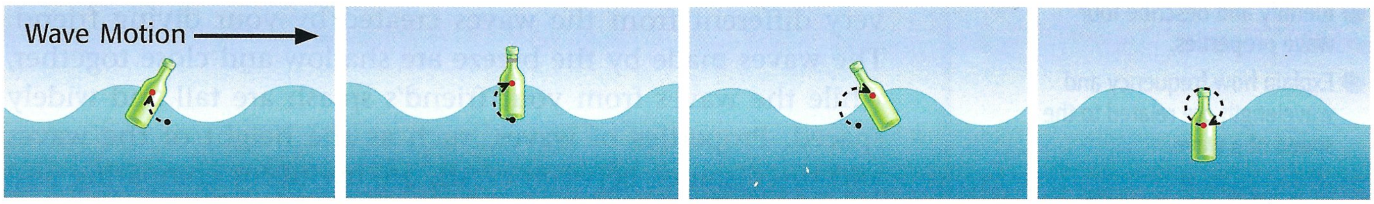


Figure 8 *Ocean waves are surface waves. A floating bottle shows the circular motion of particles in a surface wave.*

SECTION Review

Summary

- A wave is a disturbance that transmits energy.
- The particles of a medium do not travel with the wave.
- Mechanical waves require a medium, but electromagnetic waves do not.
- Particles in a transverse wave vibrate perpendicularly to the direction the wave travels.
- Particles in a longitudinal wave vibrate parallel to the direction that the wave travels.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

transverse wave	wave
longitudinal wave	medium

1. In a ___, the particles vibrate parallel to the direction that the wave travels.
2. Mechanical waves require a ___ through which to travel.
3. Any ___ transmits energy through vibrations.
4. In a ___, the particles vibrate perpendicularly to the direction that the wave travels.

Understanding Key Ideas

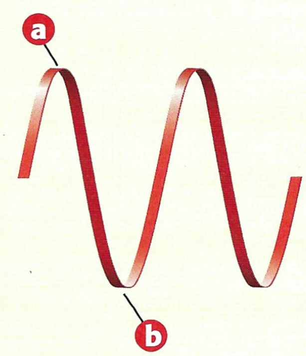
5. Waves transfer
   - **a.** matter.
   - **b.** energy.
   - **c.** particles.
   - **d.** water.
6. Name a kind of wave that does not require a medium.

Critical Thinking

7. **Applying Concepts** Sometimes, people at a sports event do "the wave." Is this a real example of a wave? Why or why not?
8. **Making Inferences** Why can supernova explosions in space be seen but not heard on Earth?

Interpreting Graphics

9. Look at the figure below. Which part of the wave is the crest? Which part of the wave is the trough?



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