17.1 Mechanical Waves

Reading Focus

Key Concepts

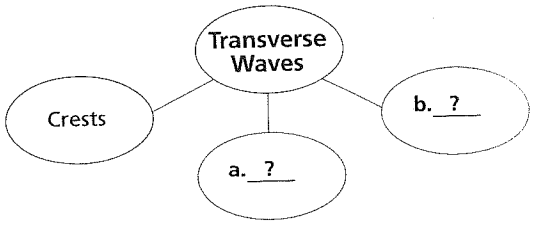
- What causes mechanical waves?
- What are the three main types of mechanical waves?

Vocabulary

- mechanical wave
- medium
- crest
- trough
- transverse wave
- compression
- rarefaction
- longitudinal wave
- surface wave

Reading Strategy

Previewing Copy the web diagram below. Use Figure 2 to complete the diagram. Then use Figure 3 and 4 to make similar diagrams for longitudinal waves and surface waves.



Have you ever gone to a wave pool at an amusement park? You can hear the laughter and screams as wave after wave passes by, giving the people a wild ride. It's obvious that waves are moving through the water, but you may not realize that the screams and laughter are also carried by waves. In this chapter, you will learn about the different kinds of mechanical waves, including sound waves.

What Are Mechanical Waves?

A **mechanical wave** is a disturbance in matter that carries energy from one place to another. Recall that energy is the ability to do work. In a wave pool, each wave carries energy across the pool. You can see the effects of a wave's energy when the wave lifts people in the water.

Mechanical waves require matter to travel through. The material through which a wave travels is called a **medium.** Solids, liquids, and gases all can act as mediums. In a wave pool, waves travel along the surface of the water. Water is the medium. Waves travel through a rope when you shake one end of it. In that case, the medium is the rope.

A mechanical wave is created when a source of energy causes a vibration to travel through a medium. A vibration is a repeating back-and-forth motion. When you shake a rope, you add energy at one end. The wave that results is a vibration that carries energy along the rope.

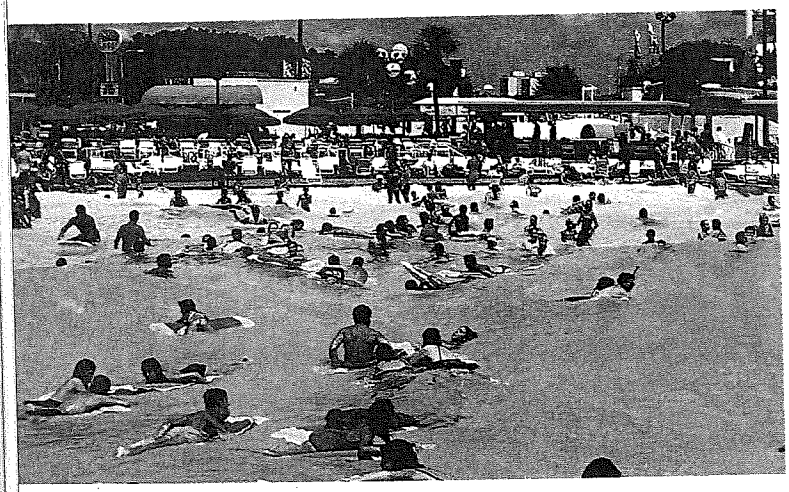


Figure 1 In a wave pool, the waves carry energy across the pool.

Types of Mechanical Waves

Mechanical waves are classified by the way they move through a medium. **The three main types of mechanical waves are transverse waves, longitudinal waves, and surface waves.**

Transverse Waves When you shake one end of a rope up and down, the vibration causes a wave. Figure 2 shows a wave in a rope at three points in time. Before the wave starts, every point on the rope is in its rest position, represented by the dashed line. The highest point of the wave above the rest position is the **crest.** The lowest point below the rest position is the **trough** (TRAWF). You can see from the ribbon attached to the rope that crests and troughs are not fixed points on a wave. In Figure 2A, the ribbon is at a crest. In Figure 2C, the ribbon is at a trough. The motion of a single point on the rope is like the motion of a yo-yo. The point vibrates up and down between a maximum and minimum height.

Notice that the wave carries energy from left to right, in a direction perpendicular to the up-and-down motion of the rope. This is a transverse wave. A **transverse wave** is a wave that causes the medium to vibrate at right angles to the direction in which the wave travels.

Have you ever shaken crumbs off a picnic blanket? This is another example of a transverse wave. Shaking one end of the blanket up and down sends a transverse wave through the blanket. The up and down motion of the blanket helps to shake off the crumbs.

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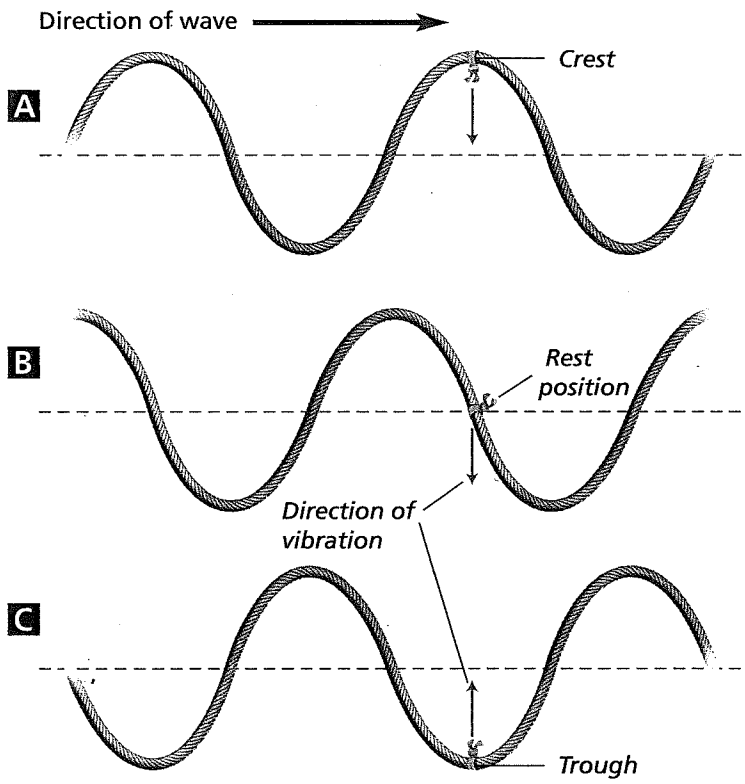

Figure 2 A transverse wave causes the medium to vibrate in a direction perpendicular to the direction in which the wave travels. In the wave shown here, each point on the rope vibrates up and down between a maximum and minimum height. **A** The ribbon is at a crest. **B** The ribbon is at the rest position. **C** The ribbon is at a trough.

Comparing and Contrasting ***How does the direction of the wave compare with the direction in which the ribbon moves?***

Quick Lab

Observing Waves in a Medium

Procedure

1. Fill a large, clear, square or rectangular container halfway with water. Add a drop of food coloring in the center of the container.
2. At the side of the container, submerge a ruler lengthwise. Move the ruler up and down to make waves.
3. Observe and record how the waves and the food coloring move.

Analyze and Conclude

1. **Comparing and Contrasting** Compare the movement of the waves with the movement of the food coloring.
2. **Formulating Hypotheses** Generate one or more hypotheses to explain the observed motion of the food coloring.

Longitudinal Waves Figure 3 shows a wave in a spring toy at two points in time. To start the wave, add energy to the spring by pushing and pulling the end of the spring. The wave carries energy along the spring from left to right. You can see in Figure 3A that when the wave starts, some of the coils are closer together than they would be in the rest position. An area where the particles in a medium are spaced close together is called a **compression** (kum PRESH un). As the compression moves to the right in Figure 3B, coils behind it are spread out more than they were in the rest position. An area where the particles in a medium are spread out is called a **rarefaction** (rehr uh FAK shun).

Look at the ribbon tied to one of the coils. The ribbon is first in a compression and then in a rarefaction. However, the ribbon and the coil it is tied to do not move along the spring. As compressions and rarefactions travel along the spring toward the right, each coil vibrates back and forth around its rest position. In this wave, the vibration is a back-and-forth motion of the coil that is parallel to, or in the same direction as, the direction in which the wave moves. This is a longitudinal wave. A **longitudinal wave** (lawn juh TOO duh nul) is a wave in which the vibration of the medium is parallel to the direction the wave travels.

Waves in springs are not the only kind of longitudinal waves. P waves (originally called primary waves) are longitudinal waves produced by earthquakes. Because P waves can travel through Earth, scientists can use these waves to map Earth's unseen interior.

Reading Checkpoint *What are compressions and rarefactions?*

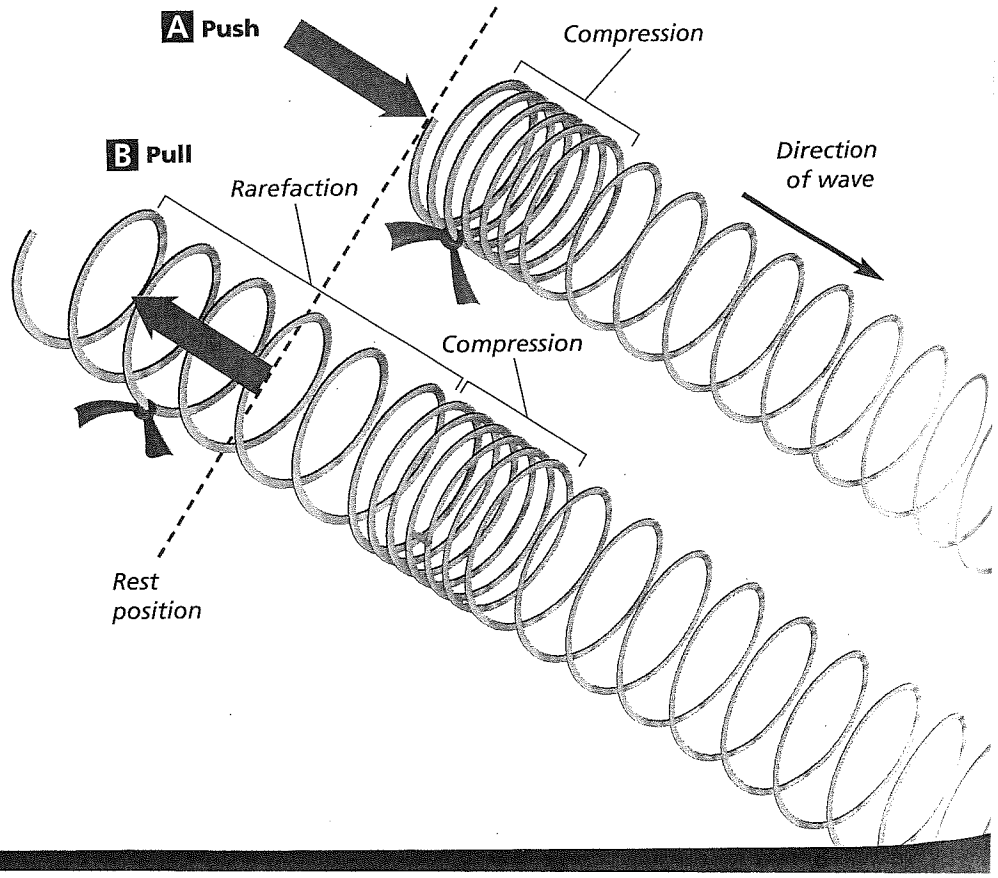

Figure 3 A longitudinal wave causes the medium to vibrate in a direction parallel to the direction in which the wave travels. Each point on the spring vibrates back and forth about its rest position. **A** When the end of the spring is pushed, a compression starts to move along the spring. **B** When the end of the spring is pulled, a rarefaction follows the compression along the spring.

Surface Waves If you ask people to describe waves, most likely they will describe ocean waves before they think of the waves that travel in a rope or a spring. Ocean waves are the most familiar kind of surface waves. A **surface wave** is a wave that travels along a surface separating two media.

The ocean wave in Figure 4 travels at the surface between water and air. The floating fishing bobber helps to visualize the motion of the medium as the wave carries energy from left to right. When a crest passes the bobber, the bobber moves up. When a trough passes, the bobber moves down. This up-and-down motion, like the motion of a transverse wave, is perpendicular to the direction in which the wave travels. But the bobber also is pushed back and forth by the surface wave. This back-and-forth motion, like the motion of a longitudinal wave, is parallel to the direction in which the wave travels. When these two motions combine in deep water, the bobber moves in a circle.

If you watched the bobber for ten minutes, it would not move closer to shore. Most waves do not transport matter from one place to another. But when ocean waves approach the shore, they behave differently. Perhaps you have seen seaweed washed ashore by breaking waves. As a wave enters shallow water, it topples over on itself because friction with the shore slows down the bottom of the wave. The top of the wave continues forward at its original speed. As a result, the wave carries the medium, along with anything floating in it, toward the shore.

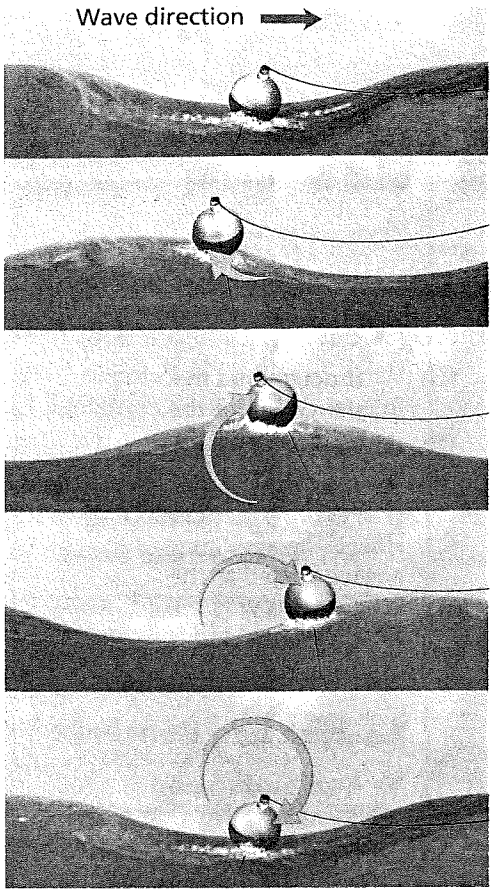

Figure 4 As the ocean wave moves to the right, the bobber moves in a circle, returning to its original position.
Making Generalizations ***If these were breaking waves near the shore, what would happen to the bobber over time?***

Section 17.1 Assessment

Reviewing Concepts

1. Describe how mechanical waves are produced.
2. List the three main types of mechanical waves.
3. For each type of wave, compare the vibration of the medium to the direction of the wave.
4. Name one example of each type of wave.

Critical Thinking

5. **Comparing and Contrasting** How are transverse and longitudinal waves similar? How are they different?
6. **Applying Concepts** A spring hangs from the ceiling. Describe how a single coil moves as a longitudal wave passes through the spring.
7. **Interpreting Diagrams** In Figure 4, why is the first position of the bobber the same as the fifth position of the bobber?

Connecting Concepts

Energy Review potential and kinetic energy in Section 15.1. Then, describe the energy changes in a single coil of a spring as longitudinal waves pass through it.