

13.1 Types of Waves

Section Learning Objectives

By the end of this section, you will be able to do the following:

- Define mechanical waves and medium, and relate the two
- Distinguish a pulse wave from a periodic wave
- Distinguish a longitudinal wave from a transverse wave and give examples of such waves

Teacher Support

Teacher Support The learning objectives in this section will help your students master the following standards:

- (7) Science concepts. The student knows the characteristics and behavior of waves. The student is expected to:
 - (A) examine and describe oscillatory motion and wave propagation in various types of media.

Section Key Terms

Mechanical Waves

What do we mean when we say something is a wave? A wave is a disturbance that travels or *propagates* from the place where it was created. Waves transfer energy from one place to another, but they do not necessarily transfer any mass. Light, sound, and waves in the ocean are common examples of waves. Sound and water waves are mechanical waves; meaning, they require a medium to travel through. The medium may be a solid, a liquid, or a gas, and the speed of the wave depends on the material properties of the medium through which it is traveling. However, light is not a mechanical wave; it can travel through a vacuum such as the empty parts of outer space.

A familiar wave that you can easily imagine is the water wave. For water waves, the disturbance is in the surface of the water, an example of which is the disturbance created by a rock thrown into a pond or by a swimmer splashing the water surface repeatedly. For sound waves, the disturbance is caused by a change in air pressure, an example of which is when the oscillating cone inside a speaker creates a disturbance. For earthquakes, there are several types of disturbances, which include the disturbance of Earth's surface itself and the pressure disturbances under the surface. Even radio waves are most

easily understood using an analogy with water waves. Because water waves are common and visible, visualizing water waves may help you in studying other types of waves, especially those that are not visible.

Water waves have characteristics common to all waves, such as amplitude, period, frequency, and energy, which we will discuss in the next section.

Teacher Support

Teacher Support

Misconception Alert

Many people think that water waves push water from one direction to another. In reality, however, the particles of water tend to stay in one location only, except for moving up and down due to the energy in the wave. The energy moves forward through the water, but the water particles stay in one place. If you feel yourself being pushed in an ocean, what you feel is the energy of the wave, not the rush of water. If you put a cork in water that has waves, you will see that the water mostly moves it up and down.

[BL][OL][AL] Ask students to give examples of mechanical and nonmechanical waves.

Pulse Waves and Periodic Waves

If you drop a pebble into the water, only a few waves may be generated before the disturbance dies down, whereas in a wave pool, the waves are continuous. A pulse wave is a sudden disturbance in which only one wave or a few waves are generated, such as in the example of the pebble. Thunder and explosions also create pulse waves. A periodic wave repeats the same oscillation for several cycles, such as in the case of the wave pool, and is associated with simple harmonic motion. Each particle in the medium experiences simple harmonic motion in periodic waves by moving back and forth periodically through the same positions.

Teacher Support

Teacher Support [BL] Any kind of wave, whether mechanical or nonmechanical, or transverse or longitudinal, can be in the form of a pulse wave or a periodic wave.

Consider the simplified water wave in Figure 13.2. This wave is an up-and-down disturbance of the water surface, characterized by a sine wave pattern. The uppermost position is called the *crest* and the lowest is the *trough*. It causes a seagull to move up and down in simple harmonic motion as the wave crests and troughs pass under the bird.

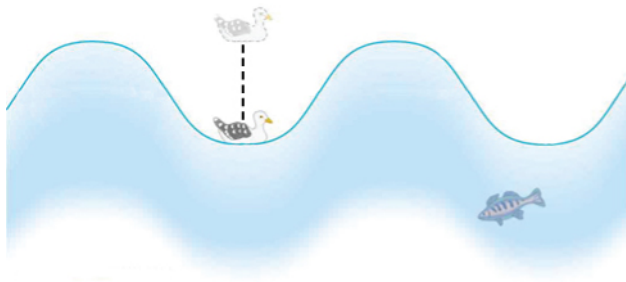


Figure 13.2 An idealized ocean wave passes under a seagull that bobs up and down in simple harmonic motion.

Longitudinal Waves and Transverse Waves

Mechanical waves are categorized by their type of motion and fall into any of two categories: transverse or longitudinal. Note that both transverse and longitudinal waves can be periodic. A transverse wave propagates so that the disturbance is perpendicular to the direction of propagation. An example of a transverse wave is shown in Figure 13.3, where a woman moves a toy spring up and down, generating waves that propagate away from herself in the horizontal direction while disturbing the toy spring in the vertical direction.

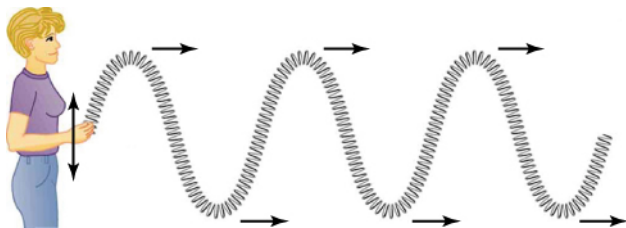


Figure 13.3 In this example of a transverse wave, the wave propagates horizontally and the disturbance in the toy spring is in the vertical direction.

In contrast, in a longitudinal wave, the disturbance is parallel to the direction of propagation. Figure 13.4 shows an example of a longitudinal wave, where the woman now creates a disturbance in the horizontal direction—which is the same direction as the wave propagation—by stretching and then compressing the toy spring.

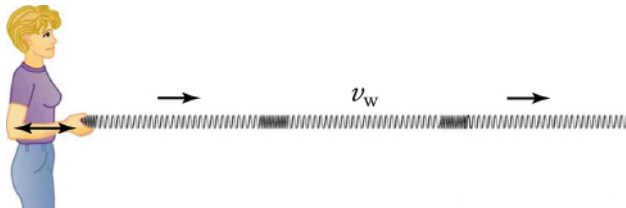


Figure 13.4 In this example of a longitudinal wave, the wave propagates horizontally and the disturbance in the toy spring is also in the horizontal direction.

Tips For Success

Longitudinal waves are sometimes called *compression waves* or *compressional waves*, and transverse waves are sometimes called *shear waves*.

Teacher Support

Teacher Support

Teacher Demonstration

Transverse and longitudinal waves may be demonstrated in the class using a spring or a toy spring, as shown in the figures.

Waves may be transverse, longitudinal, or *a combination of the two*. The waves on the strings of musical instruments are transverse (as shown in Figure 13.5), and so are electromagnetic waves, such as visible light. Sound waves in air and water are longitudinal. Their disturbances are periodic variations in pressure that are transmitted in fluids.

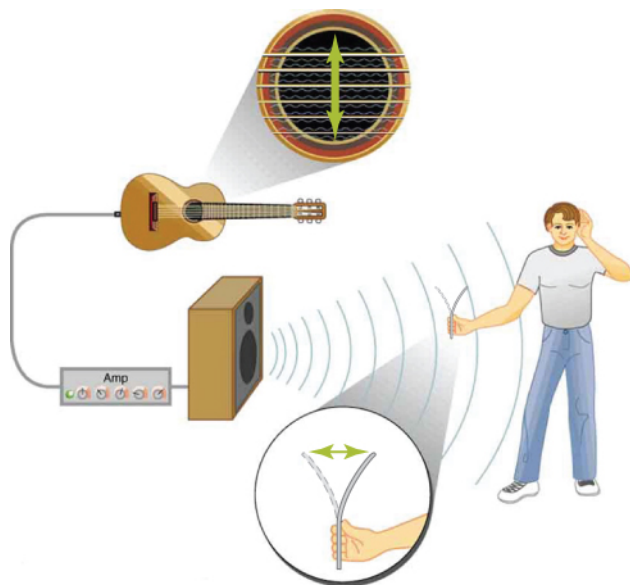


Figure 13.5 The wave on a guitar string is transverse. However, the sound wave coming out of a speaker rattles a sheet of paper in a direction that shows that such sound wave is longitudinal.

Sound in solids can be both longitudinal and transverse. Essentially, water waves are also a combination of transverse and longitudinal components, although the simplified water wave illustrated in Figure 13.2 does not show the longitudinal motion of the bird.

Earthquake waves under Earth's surface have both longitudinal and transverse components as well. The longitudinal waves in an earthquake are called pressure or P-waves, and the transverse waves are called shear or S-waves. These components have important individual characteristics; for example, they propagate at different speeds. Earthquakes also have surface waves that are similar to surface waves on water.

Teacher Support

Teacher Support Energy propagates differently in transverse and longitudinal waves. It is important to know the type of the wave in which energy is propagating to understand how it may affect the materials around it.

Watch Physics

Introduction to Waves This video explains wave propagation in terms of momentum using an example of a wave moving along a rope. It also covers the differences between transverse and longitudinal waves, and between pulse and periodic waves.

[Click to view content](#)

Watch Physics: Introduction to Waves. This video is an introduction to transverse and longitudinal waves.

[Click to view content](#)

In a longitudinal sound wave, after a compression wave moves through a region, the density of molecules briefly decreases. Why is this?

- a. After a compression wave, some molecules move forward temporarily.
- b. After a compression wave, some molecules move backward temporarily.
- c. After a compression wave, some molecules move upward temporarily.
- d. After a compression wave, some molecules move downward temporarily.

Fun In Physics

The Physics of Surfing Many people enjoy surfing in the ocean. For some surfers, the bigger the wave, the better. In one area off the coast of central California, waves can reach heights of up to 50 feet in certain times of the year (Figure 13.6).



Figure 13.6 A surfer negotiates a steep take-off on a winter day in California while his friend watches. (Ljsurf, Wikimedia Commons)

How do waves reach such extreme heights? Other than unusual causes, such as when earthquakes produce tsunami waves, most huge waves are caused simply by interactions between the wind and the surface of the water. The wind pushes up against the surface of the water and transfers energy to the water in the process. The stronger the wind, the more energy transferred. As waves start to form, a larger surface area becomes in contact with the wind, and even more energy is transferred from the wind to the water, thus creating higher waves. Intense storms create the fastest winds, kicking up massive waves that travel out from the origin of the storm. Longer-lasting storms and those storms that affect a larger area of the ocean create the biggest waves since they transfer more energy. The cycle of the tides from the Moon's gravitational pull also plays a small role in creating waves.

Actual ocean waves are more complicated than the idealized model of the simple transverse wave with a perfect sinusoidal shape. Ocean waves are examples of *orbital progressive waves*, where water particles at the surface follow a circular path from the crest to the trough of the passing wave, then cycle back again to their original position. This cycle repeats with each passing wave.

As waves reach shore, the water depth decreases and the energy of the wave is compressed into a smaller volume. This creates higher waves—an effect known as *shoaling*.

Since the water particles along the surface move from the crest to the trough, surfers hitch a ride on the cascading water, gliding along the surface. If ocean waves work exactly like the idealized transverse waves, surfing would be much less exciting as it would simply involve standing on a board that bobs up and down in place, just like the seagull in the previous figure.

Additional information and illustrations about the scientific principles behind surfing can be found in the “Using Science to Surf Better!” video.

If we lived in a parallel universe where ocean waves were longitudinal, what would a surfer's motion look like?

- a. The surfer would move side-to-side/back-and-forth vertically with no horizontal motion.

- b. The surfer would forward and backward horizontally with no vertical motion.

Check Your Understanding

Teacher Support

Teacher Support Use these questions to assess students' achievement of the section's Learning Objectives. If students are struggling with a specific objective, these questions will help identify such objective and direct them to the relevant content.

1.

What is a wave?

- a. A wave is a force that propagates from the place where it was created.
- b. A wave is a disturbance that propagates from the place where it was created.
- c. A wave is matter that provides volume to an object.
- d. A wave is matter that provides mass to an object.

2.

Do all waves require a medium to travel? Explain.

- a. No, electromagnetic waves do not require any medium to propagate.
- b. No, mechanical waves do not require any medium to propagate.
- c. Yes, both mechanical and electromagnetic waves require a medium to propagate.
- d. Yes, all transverse waves require a medium to travel.

3.

What is a pulse wave?

- a. A pulse wave is a sudden disturbance with only one wave generated.
- b. A pulse wave is a sudden disturbance with only one or a few waves generated.
- c. A pulse wave is a gradual disturbance with only one or a few waves generated.
- d. A pulse wave is a gradual disturbance with only one wave generated.

4.

Is the following statement true or false? A pebble dropped in water is an example of a pulse wave.

- a. False
- b. True

5.

What are the categories of mechanical waves based on the type of motion?

- a. Both transverse and longitudinal waves
- b. Only longitudinal waves
- c. Only transverse waves
- d. Only surface waves

6.

In which direction do the particles of the medium oscillate in a transverse wave?

- a. Perpendicular to the direction of propagation of the transverse wave
- b. Parallel to the direction of propagation of the transverse wave