CHAPTER 3
LESSON 2

# Waves

## Wave Properties

**Key Concepts**

- What are properties of waves?
- How are the frequency and the wavelength of a wave related?
- What affects wave speed?

### Before You Read

**What do you think?** Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

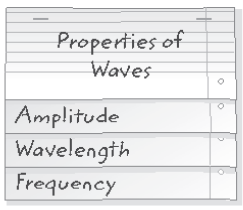
| Before | Statement | After |
|---|---|---|
| | **3.** Waves that carry more energy cause particles in a material to move a greater distance. | |
| | **4.** Sound waves travel fastest in gases, such as those in the air. | |

Mark the Text

**Underline Terms** As you read this lesson, underline each property of a wave. Then, highlight information about each property in a different color.

FOLDABLES

Make a layered book to record your notes about the properties of waves.



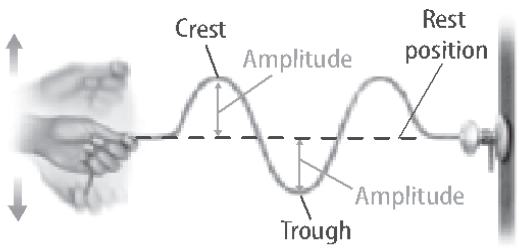

### Read to Learn

### Amplitude and Energy

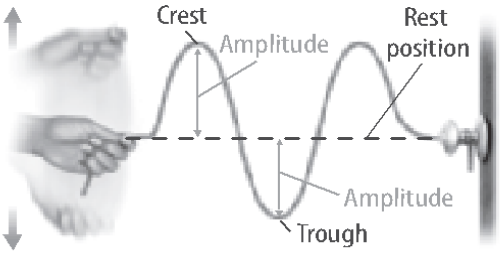
Any energy that moves through a medium moves the particles of the medium. The particles of the medium bump into each other. When they do, they might move a little or they might move a lot.

Imagine that you are floating on a raft in a pool. The water is in the rest position. Someone splashes the water and creates waves. You can barely feel them as they pass. These waves have a small amplitude. The water moves back and forth a small distance from its rest position. Now imagine that someone dives into the pool. This makes waves that bounce your raft up and down. The waves have higher crests and deeper troughs. The water moves a greater distance from its rest position to make waves with a greater amplitude. *The* **amplitude** *is the maximum distance the particles in a medium move from their rest position as the wave passes through the medium.*

For any wave, the larger the amplitude, the more energy the wave carries. The wave produced by the diver hitting the water caused a greater change than the wave produced by the gentle splash. The wave produced by the diver had more energy.




This wave has a smaller amplitude and carries less energy.




This wave has a greater amplitude and carries more energy.

## Amplitude and Energy of Transverse Waves

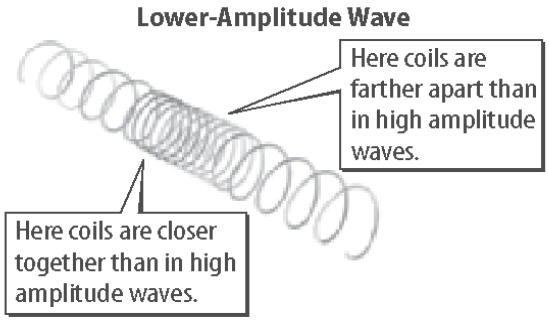
When you move a rope up and down, you produce a transverse wave with specific amplitude. For a transverse wave, the greatest distance a particle moves from the rest position is to the top of a crest or to the bottom of a trough. This distance is the amplitude of a transverse wave.

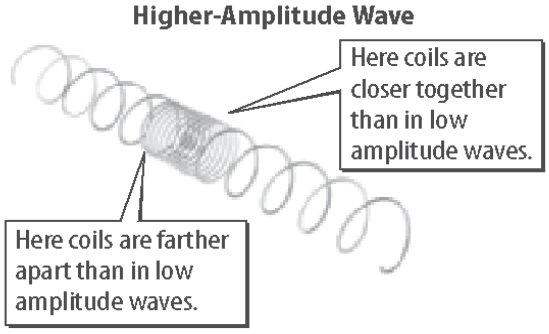
In the figure above, you can see the difference between a wave with a small amplitude and one with a large amplitude. Amplitude in a transverse wave is measured by the distance from the rest position of the medium to one of the crests or one of the troughs.

The energy carried by a transverse wave increases as the amplitude of the wave increases. Waves that have larger amplitude have more energy. Waves that have smaller amplitude have less energy.

## Amplitude and Energy of Longitudinal Waves

The amplitude of a longitudinal wave depends on the distance between the particles of the medium. The figure on the right shows large and small amplitudes in longitudinal waves. In a longitudinal wave that has a large amplitude, the particles in the compressions are close together and the particles in the rarefactions are far apart. The larger the amplitude of the wave, the more energy the wave has.




**Visual Check**

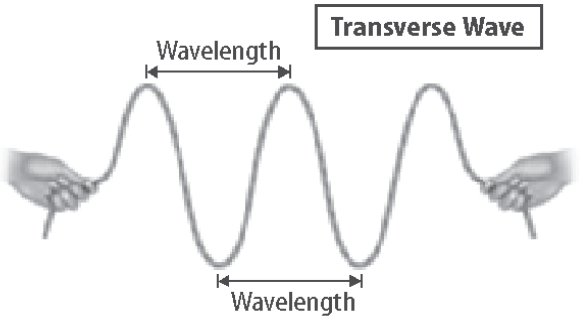
**1. Identify** How is the amplitude of a transverse wave measured?

**Visual Check**

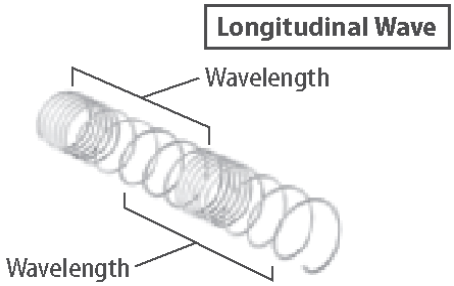
**2. Identify** What is the difference between longitudinal waves that have different amplitudes?

**Reading Check**

**3. Explain** How can you tell which has the greater amount of energy when two longitudinal waves are traveling through the same medium?




Wavelength is the distance from one crest to the next crest or from one trough to the next trough.




Wavelength is the distance from one compression to the next compression or from one rarefaction to the next rarefaction.

**Visual Check**

**4. Describe** How is wavelength measured in a transverse wave?

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_____

_____

**Think it Over**

**5. Explain** If you are measuring the wavelength of a transverse wave, why doesn't it matter whether you measure it between crests or between troughs?

_____

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**Key Concept Check**

**6. Identify** What are three properties of waves?

_____

_____

_____

# Wavelength

*The* **wavelength** *of a wave is the distance from one point on a wave to the same point on the next wave.* The figure above shows how wavelength is measured for transverse waves and for longitudinal waves. To measure the wavelength of a transverse wave, you can measure the distance from one crest to the next crest. Or, you can measure from one trough to the next trough. In the same wave, both of these distances will be the same.

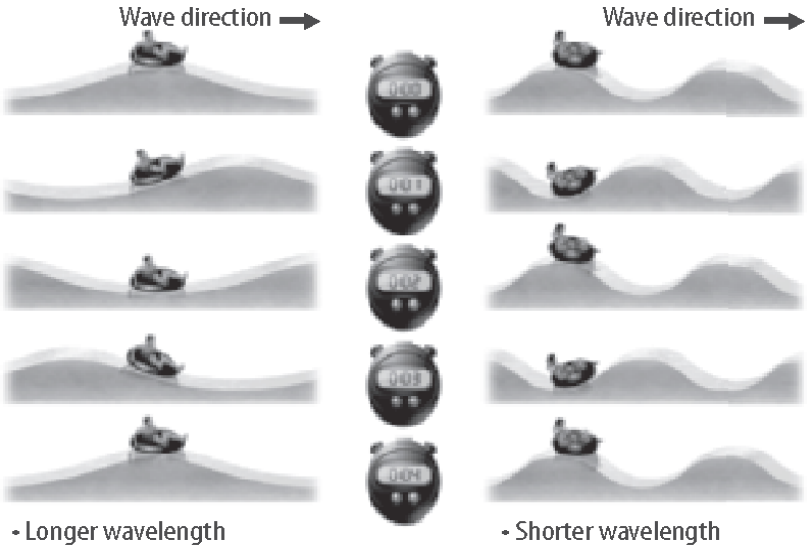
To measure the wavelength of a longitudinal wave, you can measure the distance from one compression to the next compression. Or, you can measure from one rarefaction to the next rarefaction. In the same wave, both of those distances will be the same. Wavelength is measured in units of distance, such as meters.

# Frequency

Waves have another property called frequency. *The* **frequency** *of a wave is the number of wavelengths that pass by a point each second.* Frequency is determined by measuring how quickly the object or material producing the wave vibrates. Each vibration of the object produces one wavelength. When the object vibrates faster, the waves will have a higher frequency. The frequency of a wave will be equal to the number of vibrations the vibrating object makes each second.

## The Unit for Frequency

The SI unit for frequency is hertz (Hz). A wave with a frequency of 2 Hz means that two wavelengths pass the same point each second. The unit Hz is the same unit as 1/s.




- Longer wavelength
- Lower frequency
- One complete wave passes in four seconds.

- Shorter wavelength
- Higher frequency
- Two complete waves pass in four seconds.

## Wavelength and Frequency

The wavelength and the frequency of a wave are always related. When the frequency of a wave changes, the wavelength also changes. The figure above shows how frequency and wavelength are related. Notice that the wavelength of the wave on the left is longer than that of the waves on the right. Waves with a longer wavelength have a lower frequency. Waves with a shorter wavelength have a higher frequency. As the frequency of a wave increases, its wavelength decreases.

For the wave on the left, one wavelength passes in 4 s. For the waves on the right, two wavelengths pass in 4 s. To calculate the frequency of waves, divide the number of wavelengths by the time it takes for those wavelengths to pass. For the wave on the left, the frequency is 1 wavelength divided by 4 s, which is 0.25 Hz. The wave on the right has a frequency of 2 wavelengths divided by 4 s, which is 0.5 Hz.

**Visual Check**

**7. Identify** What are the frequencies of the waves in each column?

**Key Concept Check**

**8. Describe** How does the wavelength of a wave change if its frequency decreases?

# Wave Speed

Different types of waves travel at different speeds. During a thunderstorm, you might hear thunder a few seconds after you see lightning. Light waves move about 1 million times faster than the sound waves you hear as thunder.

## Wave Speed Through Different Materials

The same type of waves travel at different speeds in different materials. Mechanical waves, such as sound waves, usually travel fastest in solids and slowest in gases. The table to the right shows the speed of sound in several different materials. Mechanical waves also usually travel faster as the temperature of the medium increases. Electromagnetic waves move fastest in empty space and slowest in solids.

**Speed of Sound Waves in Different Materials**

| Material | Wave Speed (m/s) |
|---|---|
| **Gases (0°C)** | |
| Oxygen | 316 |
| Dry air | 331 |
| **Liquids (25°C)** | |
| Ethanol | 1,207 |
| Water | 1,500 |
| **Solids** | |
| Ice | 3,850 |
| Aluminum | 6,420 |

**Visual Check**

**9. Identify** Which solid listed in the table does sound move fastest through?

_____

**Key Concept Check**

**10. Identify** What two things does wave speed depend on?

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## Calculating Wave Speed

The speed of a wave depends on its wavelength and its frequency. You can calculate the speed of a wave by multiplying its wavelength by its frequency, as shown below. The symbol for wavelength is λ, which is the Greek letter *lambda*.

**Wave Speed Equation**

wave speed (in m/s) = frequency (in Hz) × wavelength (in m)

$$s = f\lambda$$

When you multiply wavelength and frequency, the result has units of m × Hz. This equals m/s—the unit for speed.

**Math Skills**

A mosquito beating its wings produces sound waves with a frequency of 700 Hz and a wavelength of 0.5 m.

frequency: $f = 700$ Hz

wavelength: $\lambda = 0.5$ m

**a.** Find: wave speed: $s$

$$s = f\lambda$$

**b.** Substitute:

$$s = 700 \times 0.5 = 350$$

**c.** Determine the units:

units of $s$ = (units of $f$) × (units of λ)

= (Hz) × (m)

= (1/s) × (m) = m/s

**11. Use a Simple Equation** How fast are the sound waves of the beating mosquito wings traveling?

_____

# After You Read

## Mini Glossary

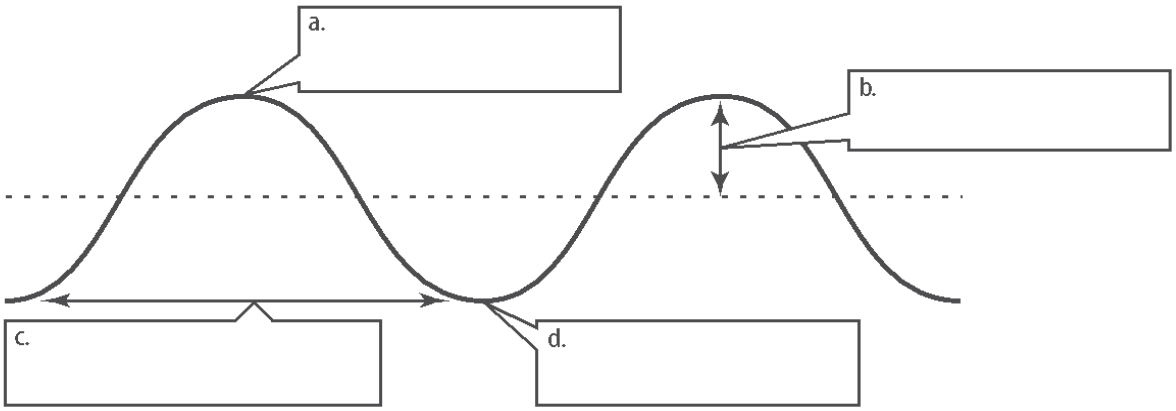
**amplitude (AM pluh tewd):** the maximum distance the particles in a medium move from their rest position as the wave passes through the medium

**frequency (FREE kwun see):** the number of wavelengths that pass by a point each second

**wavelength:** the distance from one point on a wave to the same point on the next wave

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that tells how amplitude and frequency can describe a wave.

2. Label the parts of the transverse wave in the diagram below.




3. Explain how multiplying a wave's wavelength by its frequency gives the wave's speed.



**What do you think NOW?**

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON