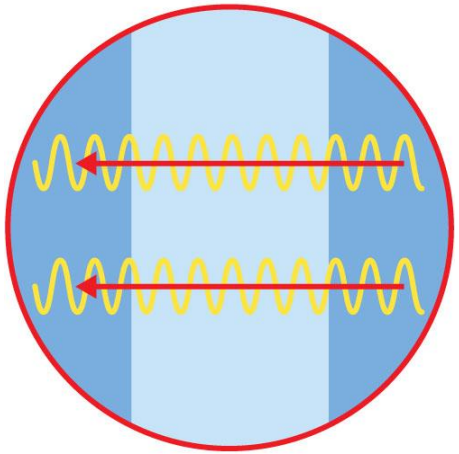
Chapter Menu



How do waves travel through matter?

Get Ready

What do you think?

Before you begin, decide if you agree or disagree with each of these statements. As you view this presentation, see if you change your mind about any of the statements.

Get Ready

Do you agree or disagree?

1. Waves carry matter as they travel from one place to another.
2. Sound waves can travel where there is no matter.
3. Waves that carry more energy cause particles in a material to move a greater distance.

Get Ready

Do you agree or disagree?

4. Sound waves travel fastest in gases, such as air.

5. When light waves strike a mirror, they change direction.

6. Light waves travel at the same speed in all materials.

Lesson 1

What are waves?

Key Concepts

- What is a wave?
- How do different types of waves make particles of matter move?
- Can waves travel through empty space?

Lesson 1

What are waves?

Vocabulary

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

What are waves?

- A **wave** is a disturbance that transfers energy from one place to another without transferring matter.
- Waves transfer energy away from the source of the energy.
- Waves leave matter in the same place after they pass.

What are waves? (cont.)

KEY CONCEPT CHECK

What is a wave?

Water waves transfer energy across the pool, but not matter. As a result, the raft does not move along with the waves.

The raft is at rest in its initial position.

A wave begins to lift the raft upward when it reaches the raft.

The wave transfers energy to the raft as it lifts it upward.

Water waves transfer energy across the pool, but not matter. As a result, the raft does not move along with the waves.

The wave passes the raft and continues to move across the pool.

The raft returns to its initial position after the wave passes.

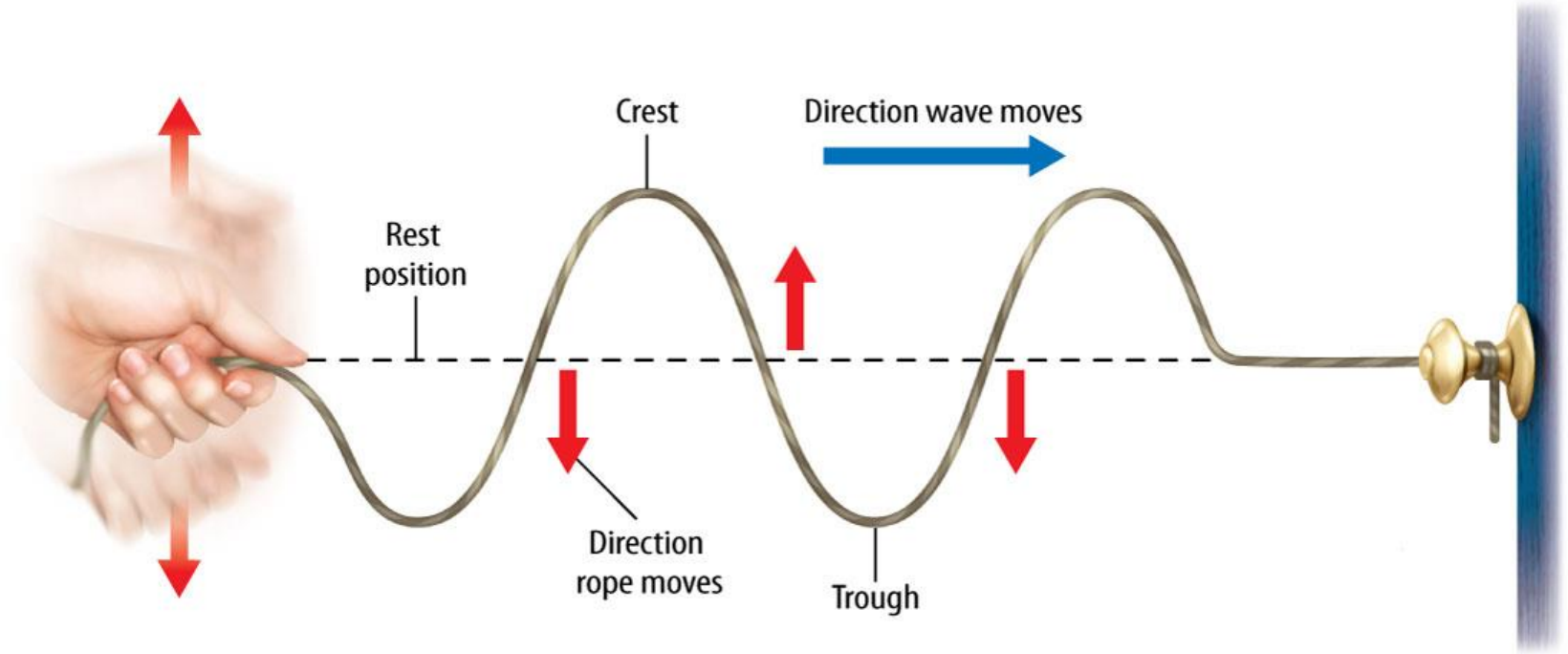
Mechanical Waves

- A wave that can travel only through matter is a **mechanical wave**.
- Mechanical waves cannot move through a vacuum.
- A material in which a mechanical wave travels is called a **medium**.

Mechanical Waves (cont.)

- A **transverse wave** makes particles in a medium move at right angles, or perpendicular, to the direction the wave travels.
- The highest points on a transverse wave are **crests**.
- The lowest points on a transverse wave are **troughs**.

In a transverse wave, particles move at right angles to the direction the wave travels.



Get Animated

Mechanical Waves (cont.)

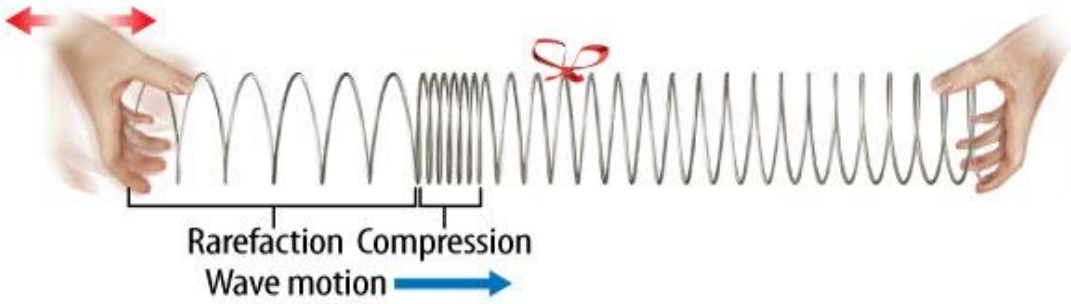
Key Concept Check

How do particles move in a transverse wave?

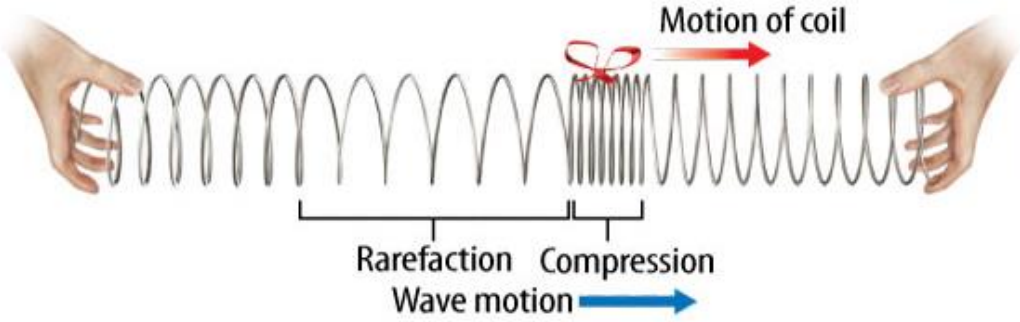
Mechanical Waves (cont.)

- A **longitudinal wave** makes the particles in a medium move parallel to the direction that the wave travels.
- The regions of a longitudinal wave where the particles in the medium are closest together are **compressions**.
- The regions of a longitudinal wave where the particles are farthest apart are **rarefactions**.

Longitudinal Waves



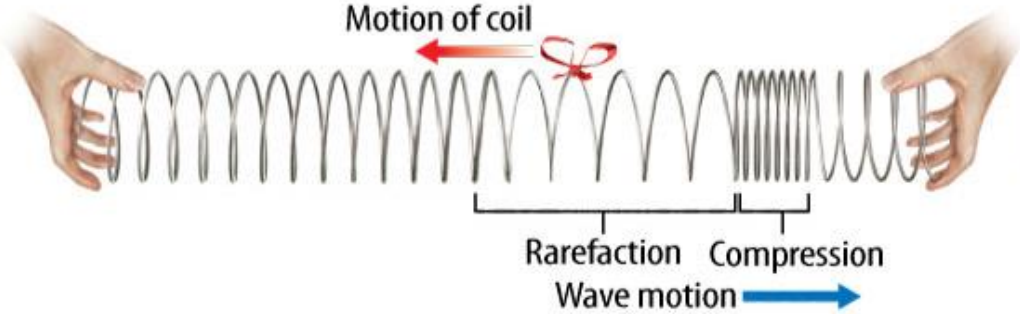
A back-and-forth movement of the hand on the left produces a longitudinal wave that travels to the right.



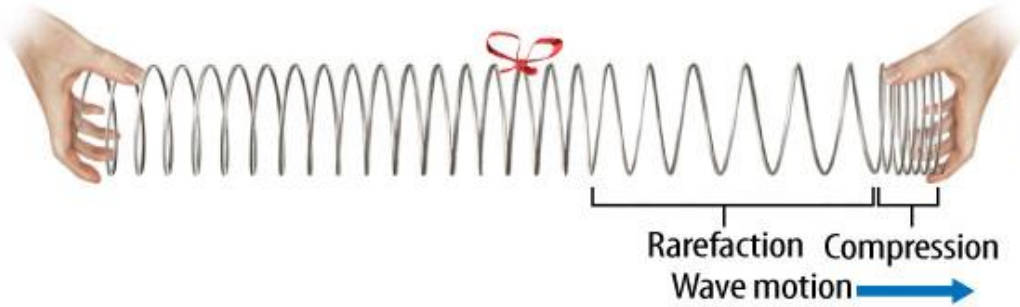
The wave makes the coil with the yarn move to the right as the compression of the wave reaches that coil.

Get Animated

Longitudinal Waves



The wave makes the coil with the yarn move to the left as the rarefaction of the wave reaches that coil.



The coil with the ribbon returns to its original position after the wave passes.

Mechanical Waves (cont.)

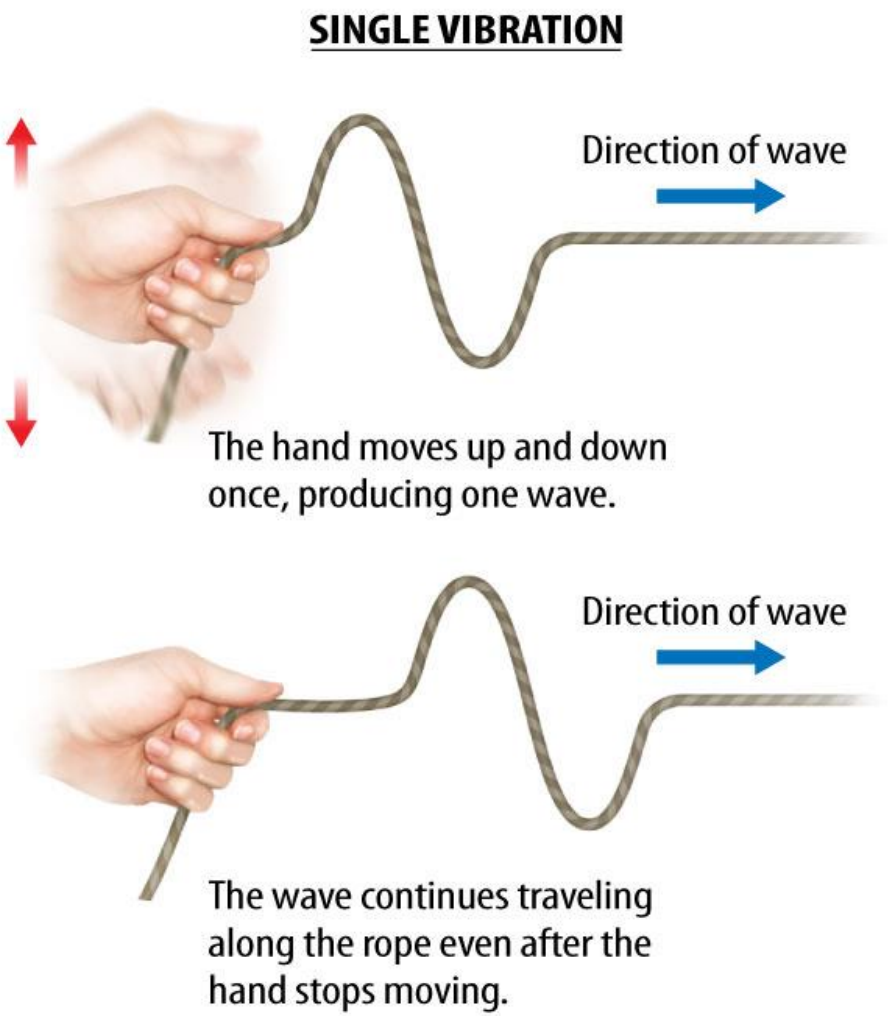
Key Concept Check

How do particles move in a longitudinal wave?

Mechanical Waves (cont.)

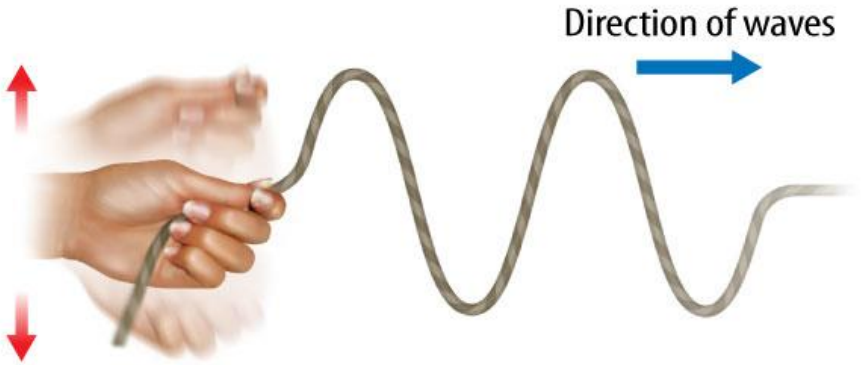
- A vibration is a back-and-forth or an up-and-down movement of an object.
- Vibrating objects are the sources of energy that produce mechanical waves.

Vibrations produce waves that keep traveling even when the vibrations stop.



Vibrations produce waves that keep traveling even when the vibrations stop.

MULTIPLE VIBRATIONS



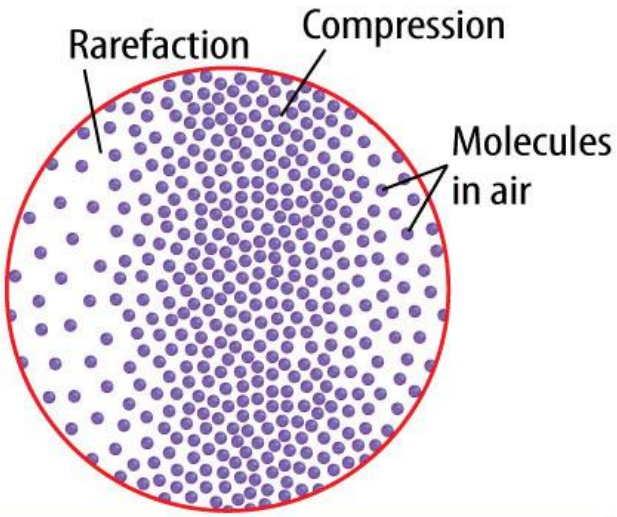
The hand moves up and down repeatedly, creating multiple waves.

The waves continues traveling along the rope even after the hand stops moving.

Types of Mechanical Waves

- All mechanical waves travel only in matter.
- Sound waves and waves produced by earthquakes are mechanical waves that travel in different mediums.

Types of Mechanical Waves

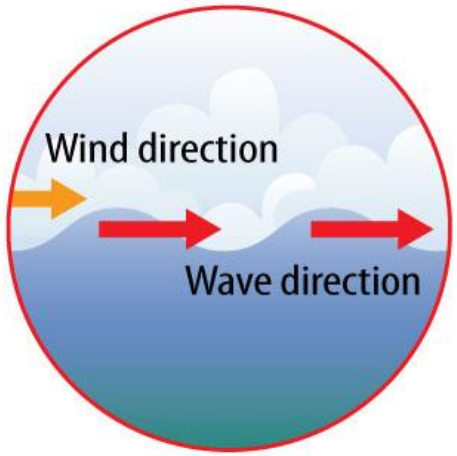


The movement of the speaker cone produces compressions and rarefactions.

Sound Waves

- Sound waves are longitudinal waves that travel in solids, liquids, and gases.
- A sound wave is made of a series of compressions and rarefactions.
- A paper cone inside the speaker vibrates in and out to produce sound waves.
- The speaker makes a compression when the speaker cone pushes air molecules together as it moves outward.
- The speaker makes a rarefaction when the speaker cone moves inward and the air molecules spread out.

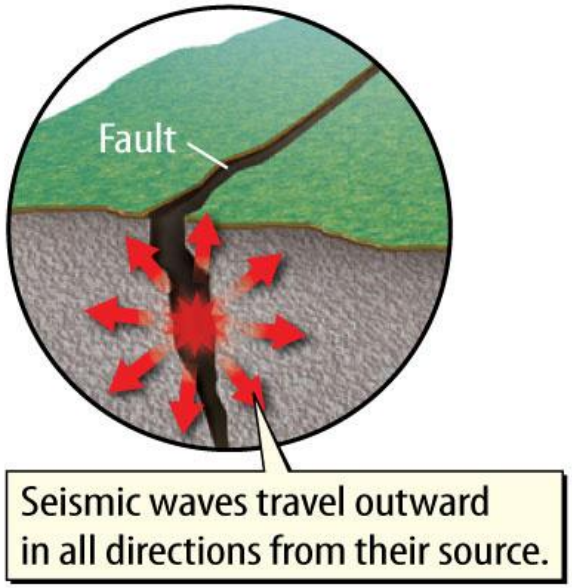
Types of Mechanical Waves



Water Waves

- Water waves are a combination of transverse waves and longitudinal waves.
- Wind produces most waves in oceans and lakes by pushing on the surface of the water.

Types of Mechanical Waves



Seismic Waves

- Waves in Earth's crust, called seismic (SIZE mihk) waves, cause earthquakes.
- Seismic waves are mechanical waves that travel within Earth and on Earth's surface.
- There are both longitudinal and transverse seismic waves.
- In some places, parts of Earth's upper layers can move along a crack called a fault.
- The movement of Earth's upper layers along a fault produces seismic waves.

Electromagnetic Waves

An **electromagnetic wave** can travel through a vacuum and through matter.

WORD ORIGIN

electromagnetic

from Greek *elektron*, means “amber” and *magnes*, means “lodestone”

Electromagnetic Waves (cont.)

Light is an electromagnetic wave.

KEY CONCEPT CHECK

Identify a type of wave that can travel through a vacuum.

Electromagnetic Waves (cont.)

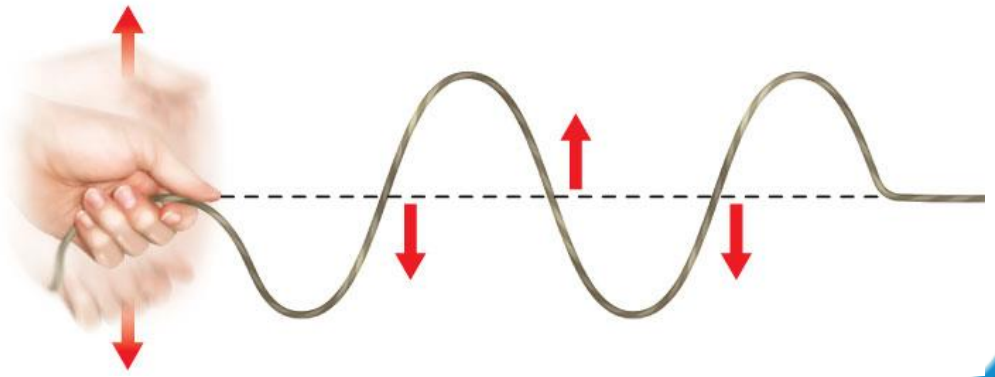
- Other types of electromagnetic waves include radio waves, microwaves, infrared waves, and ultraviolet waves.
- Every object gives off electromagnetic waves.
- Humans and other objects near human body temperature also give off mostly infrared waves.

Electromagnetic Waves (cont.)

- Electromagnetic waves carry energy that scientists call radiant energy.
- Infrared and visible light waves carry about 92 percent of the radiant energy that reaches Earth from the Sun.
- Ultraviolet waves carry about 7 percent of the Sun's energy.

Summary

- Waves, such as those from a burning candle, the Sun, or a loudspeaker, transfer energy away from the source of the wave.
- A transverse wave makes particles in a medium move at right angles to the direction of the wave.



Summary

- A longitudinal wave makes the particles in a medium move in a direction that is parallel to the direction the wave travels.

Lesson Review

Which term refers to the highest points on a transverse wave?

A. trough

B. rarefaction

C. medium

D. crest

Lesson Review

Which can be described as a wave that can travel only through matter?

A. transverse wave

B. mechanical wave

C. longitudinal wave

D. electromagnetic wave

Lesson Review

Which is the only type of wave that can travel through a vacuum?

A. electromagnetic wave

B. longitudinal wave

C. mechanical wave

D. transverse wave

Lesson Review

What do you think NOW?

Do you agree or disagree?

1. Waves carry matter as they travel from one place to another.
2. Sound waves can travel where there is no matter.

Lesson 2

Wave Properties

Key Concepts

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

Lesson 2

Wave Properties

Vocabulary

- amplitude
- wavelength
- frequency

Amplitude and Energy

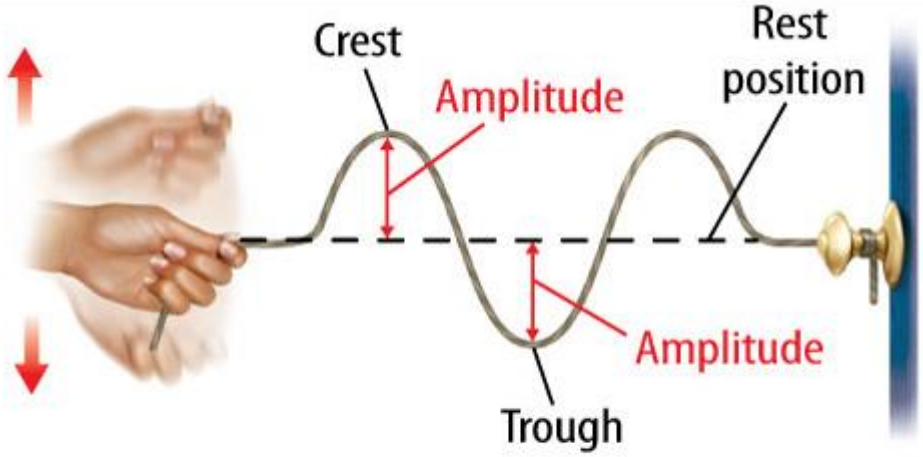
The **amplitude** of a transverse wave is the maximum distance the particles in a medium move from their rest position as the wave passes.

WORD ORIGIN

amplitude

from Latin *amplitudinem*, means “width”

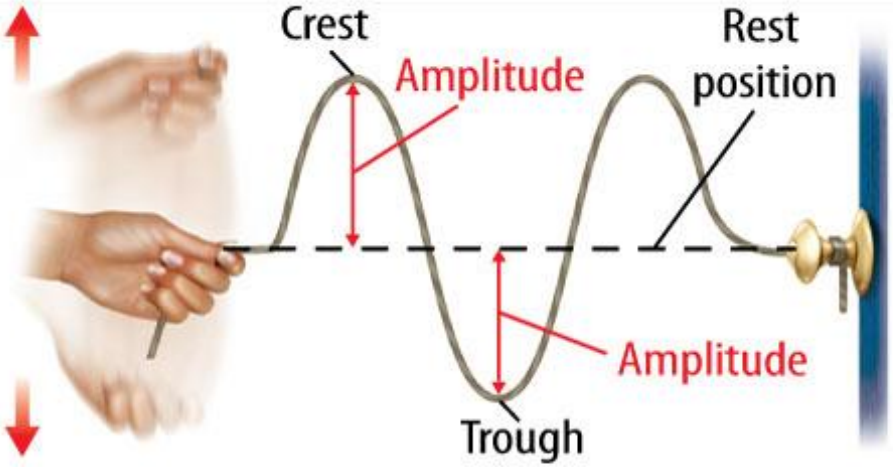
The amplitude of a transverse wave is the distance from the resting position to a crest or a trough.



This wave has a smaller amplitude and carries less energy.

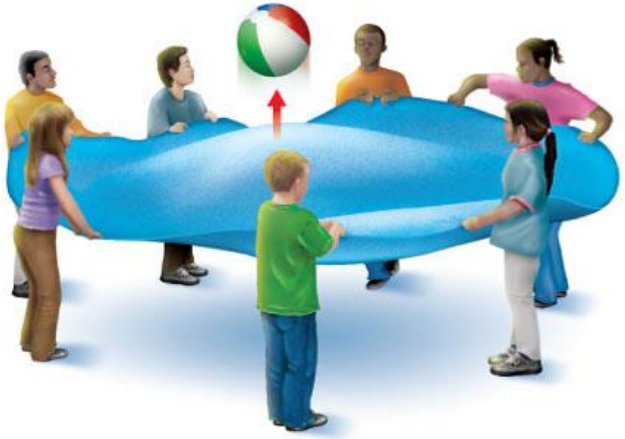
Get Animated

The larger the amplitude, the more energy the wave carries.

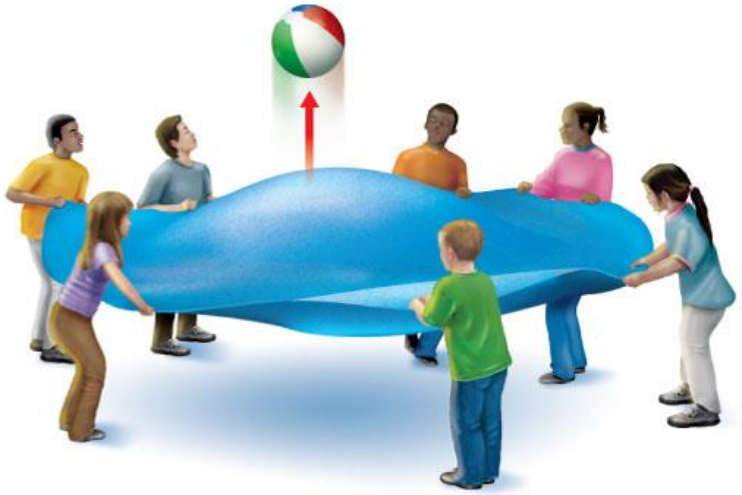


This wave has a greater amplitude and carries more energy.

The wave with the larger amplitude carries more energy and makes the ball bounce higher.



Lower Amplitude Wave
The parachute transfers less energy to the ball.

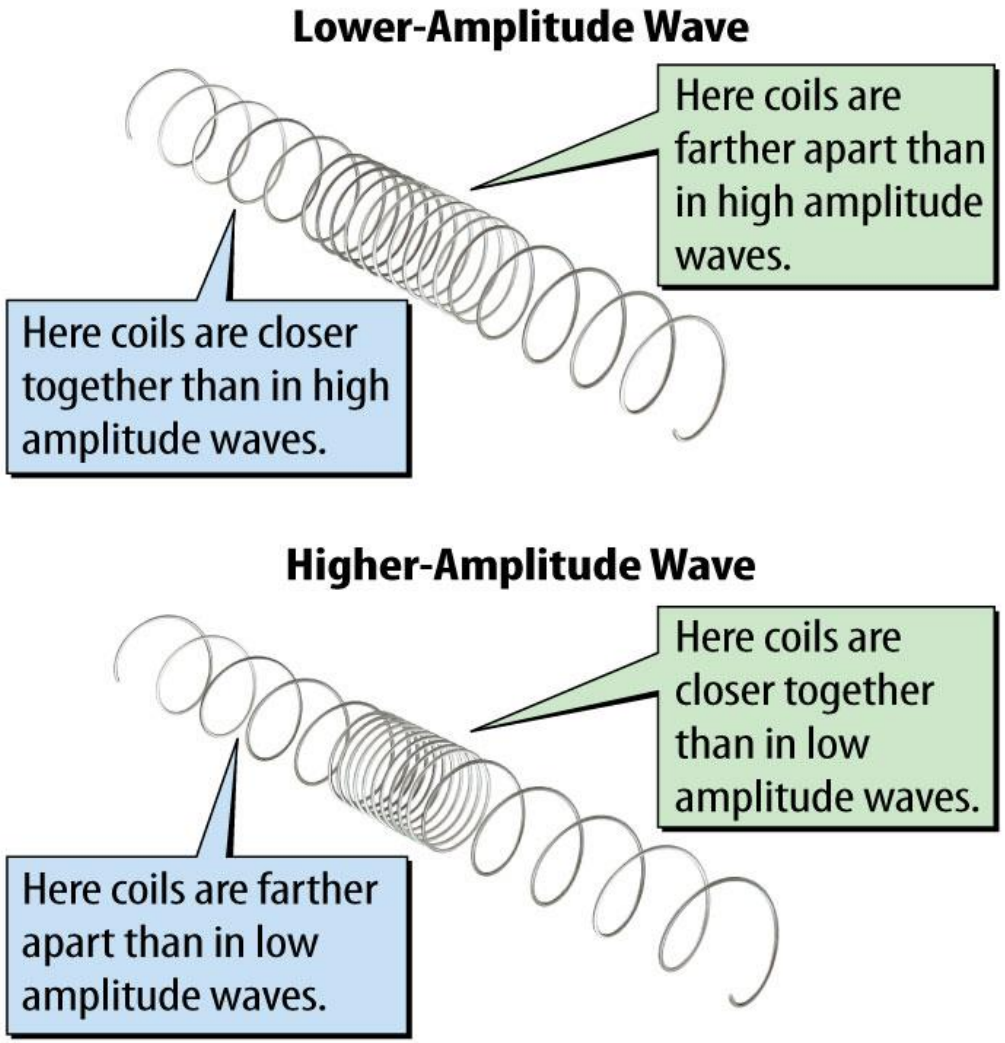


Higher Amplitude Wave
The parachute transfers more energy to the ball.

Amplitude and Energy (cont.)

- The amplitude of a longitudinal wave depends on the distance between particles in the compressions and rarefactions.
- When the amplitude of a longitudinal wave increases, the particles in the medium get closer together in the compressions and farther apart in the rarefactions.

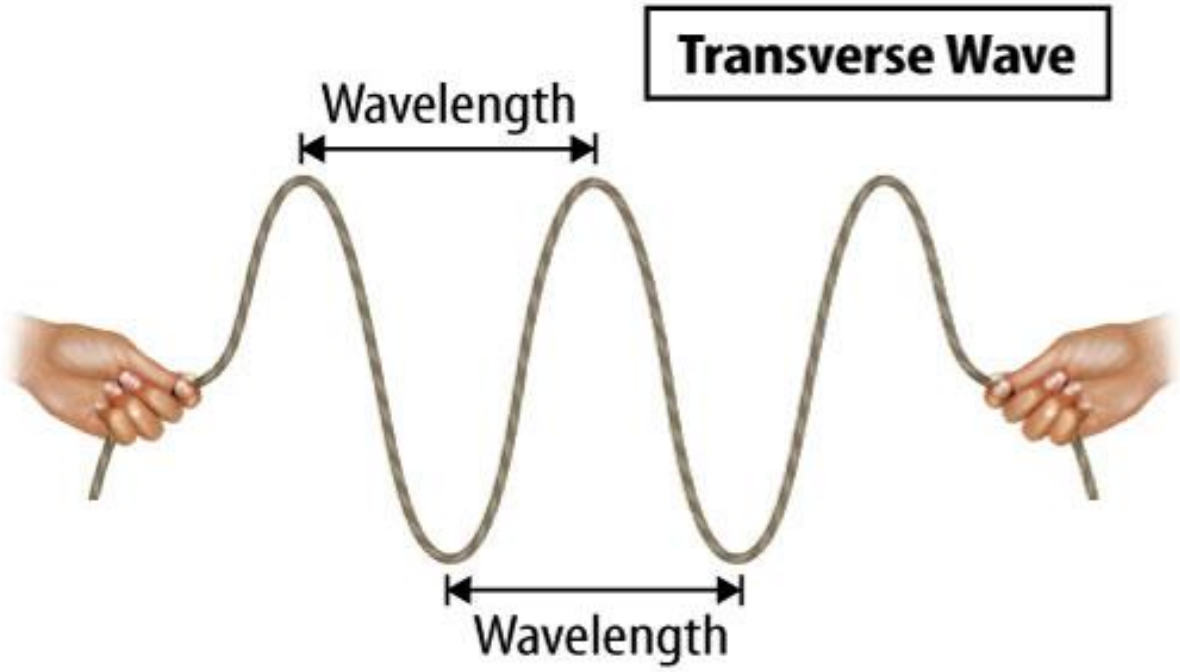
The amplitude of a longitudinal wave on a spring depends on the spacing of the coils in the compressions and rarefactions.



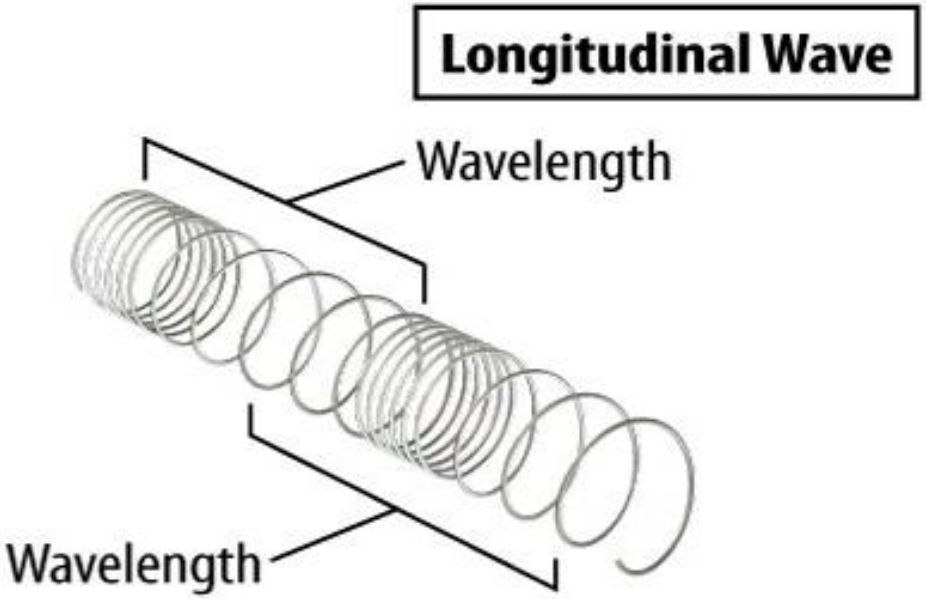
Wavelength

- The **wavelength** of a wave is the distance from one point on a wave to the nearest point just like it.
- Wavelength is measured in units of distance, such as meters.

To measure the wavelength of a transverse wave, you can measure the distance from one crest to the next crest or from one trough to the next trough.



To measure the wavelength of a longitudinal wave, you can measure the distance from one compression to the next compression or from one rarefaction to the next rarefaction.



Frequency

- The **frequency** of a wave is the number of wavelengths that pass by a point each second.
- Frequency is related to how rapidly the object or material producing the wave vibrates.
- Each vibration of the object produces one wavelength.

Frequency (cont.)

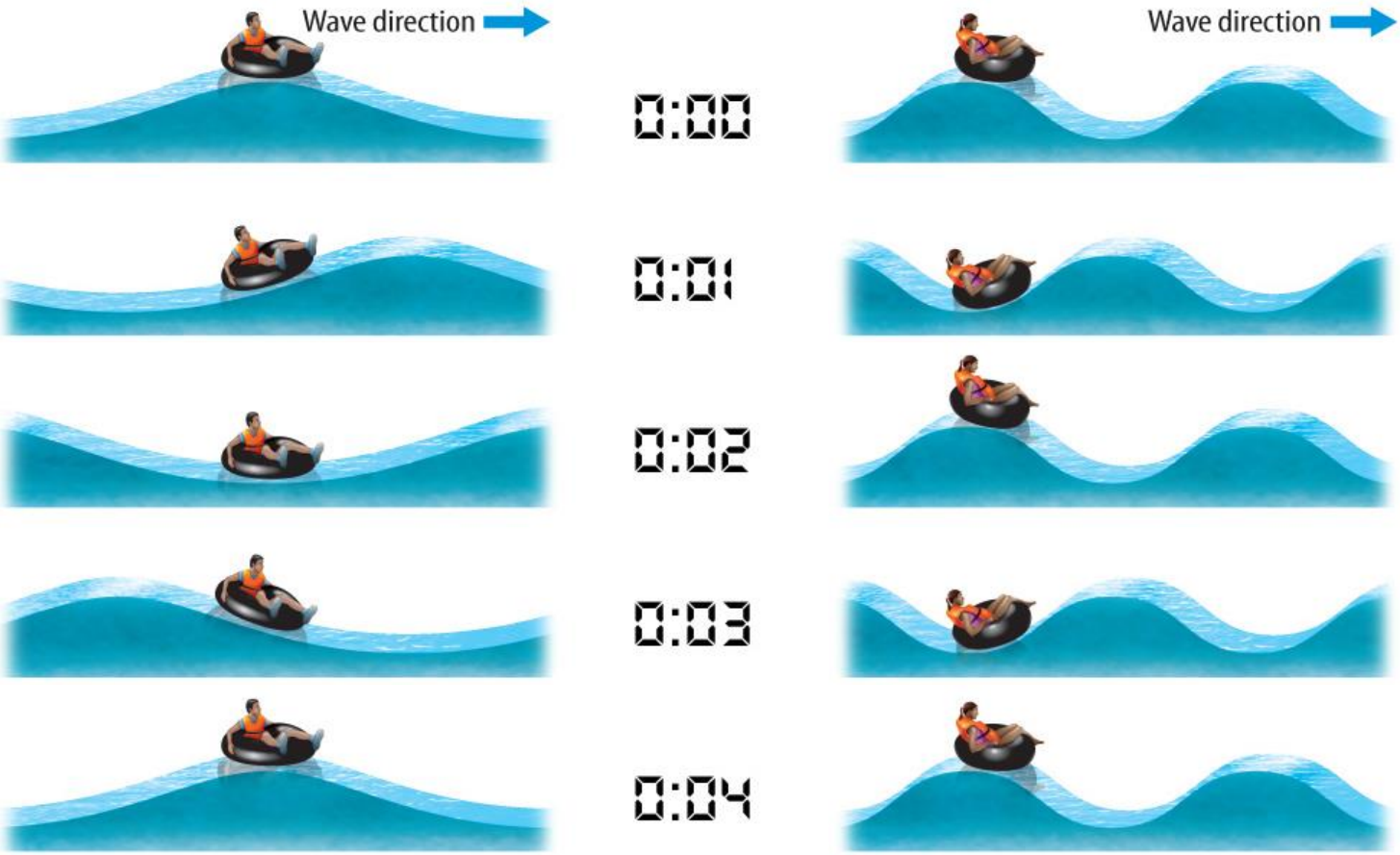
KEY CONCEPT CHECK

What are the three properties of waves?

Frequency (cont.)

- The frequency of a wave is the same as the number of vibrations the vibrating object makes each second.
- The SI unit for frequency is hertz (Hz).
- To calculate the frequency of waves, divide the number of wavelengths by the time.
- As the frequency of a wave increases, the wavelength decreases.

Frequency and Wavelength



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

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

Frequency (cont.)

KEY CONCEPT CHECK

How does the wavelength change if the frequency of a wave decreases? What if the frequency increases?

Wave Speed

- Different types of waves travel at different speeds.
- The same type of waves travel at different speeds in different materials.
- Temperature also affects the speed at which waves travel.

Speed of Sound Waves in Different Material

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

Wave Speed (cont.)

KEY CONCEPT CHECK

What does wave speed depend on?

Wave Speed (cont.)

You can calculate the speed of a wave by multiplying its wavelength and its frequency together.

Wave Speed Equation

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

$$s = f\lambda$$

Wave Speed (cont.)

Math Skills Use a Simple Equation

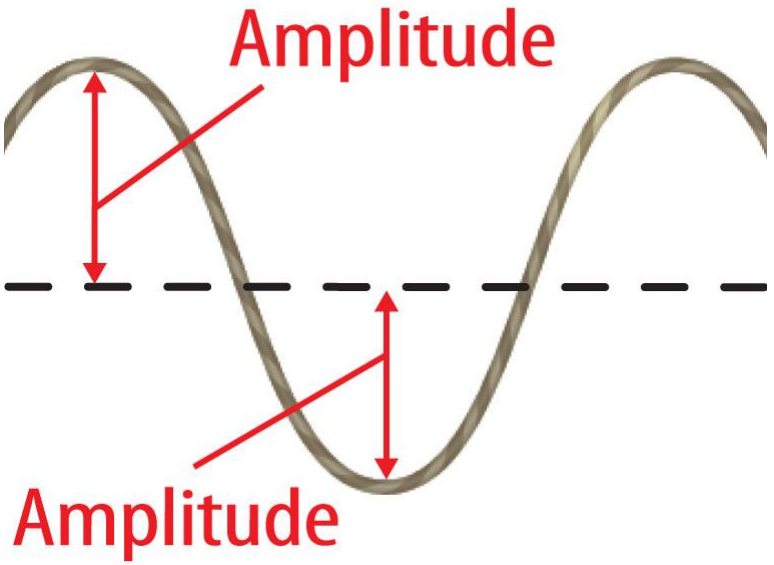
Solve for Wave Speed A mosquito beating its wings produces sound waves with a frequency of 700 Hz and a wavelength of 0.5 m. How fast are the sound waves traveling?

1. **This is what you know:** frequency: $f = 700$ Hz; wavelength: $\lambda = 0.5$ m
2. **This is what you need to find:** wave speed: s
3. **Use this formula:** $s = f\lambda$
4. **Substitute:** the values for f and λ into the formula and multiply: $s = (700\text{ Hz}) \times (0.5\text{ m}) = 350\text{ m/s}$
5. **Determine the units:** units of v = (units of f) × (units of λ) = (Hz) × (m) = (1/s) × (m) = m/s

Answer: The wave speed is 350 m/s.

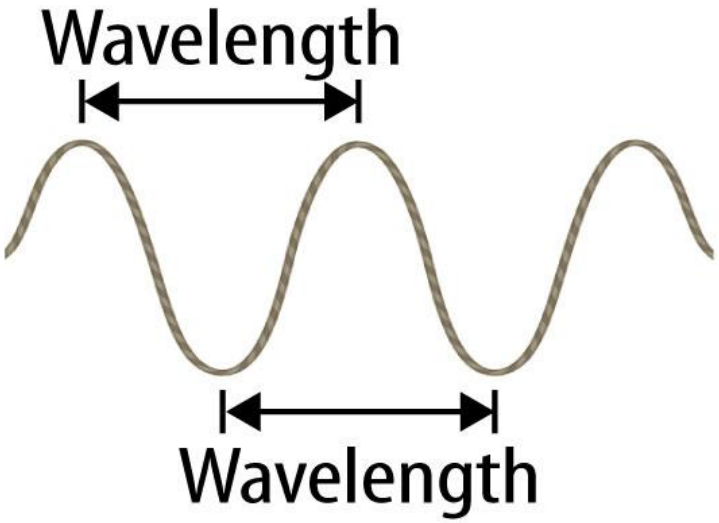
Summary

- The amplitude of a transverse wave is the maximum distance the particles in a medium move from the rest position.



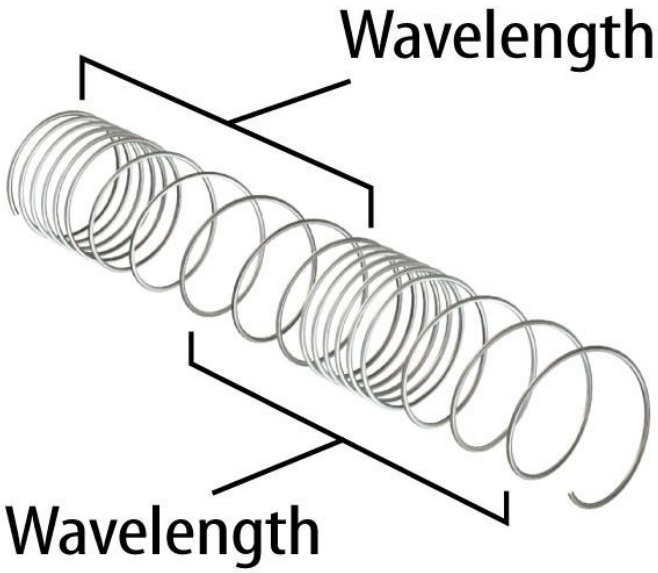
Summary

- The wavelength of a transverse wave is the distance from one point on a wave to the nearest point just like it, such as from crest to crest or from trough to trough.



Summary

- The wavelength of a longitudinal wave is the distance from one point on a wave to the nearest point just like it, such as from compression to compression or from rarefaction to rarefaction.



Lesson Review

To measure the wavelength of a transverse wave, you can measure the distance from one crest to which of these?

A. the next crest

B. the next trough

C. the next compression

D. the next rarefaction

Lesson Review

Which refers to the number of wavelengths that pass by a point each second?

A. amplitude

B. compression

C. frequency

D. wavelength

Lesson Review

What can you calculate by multiplying wavelength and frequency?

A. amplitude

B. vibration

C. wave height

D. wave speed

Lesson Review

What do you think NOW?

Do you agree or disagree?

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 air.

Lesson 3

Wave Interactions

Key Concepts

- How do waves interact with matter?
- What are reflection, refraction, and diffraction?
- What is interference?

Lesson 3

Wave Interactions

Vocabulary

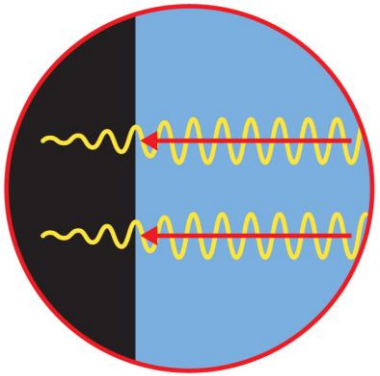
- absorption
- transmission
- reflection
- law of reflection
- refraction
- diffraction
- interference

Interaction of Waves with Matter

- Waves can be reflected by matter or they can change direction when they travel from one material to another.
- As waves pass through matter, some of the energy they carry can be transferred to matter.

Interaction of Waves with Matter (cont.)

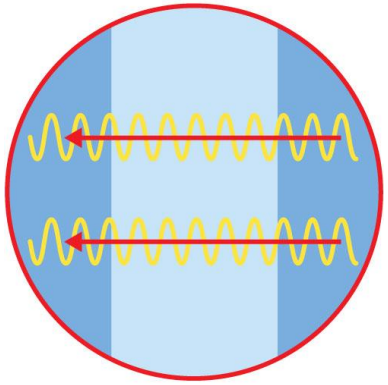
- **Absorption** occurs when energy carried by a wave transfers to the material in which it is traveling.



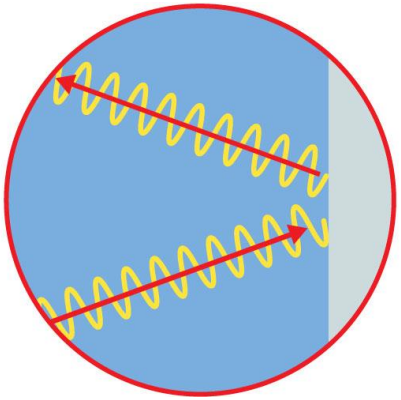
- The amount of energy absorbed depends on the type of wave and the material in which it moves.
- All materials absorb electromagnetic waves, although some materials absorb more electromagnetic waves than others.

Interaction of Waves with Matter (cont.)

Transmission occurs when waves pass through a material.



Interaction of Waves with Matter (cont.)



- **Reflection** occurs when waves bounce off the surface of a material.
- An object that reflects all visible light would appear white, while an object that reflects no visible light would appear black.
- All types of waves, including sound waves, light waves, and water waves, can reflect when they hit a surface.

Interaction of Waves with Matter (cont.)

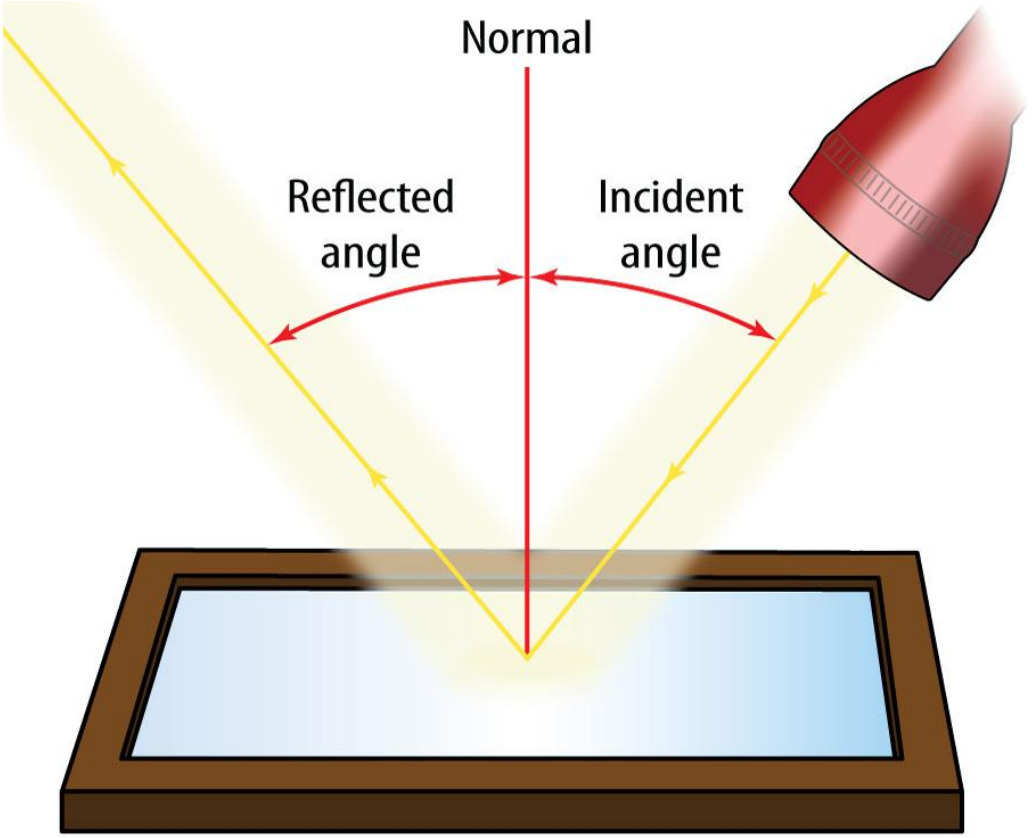
KEY CONCEPT CHECK

What are three ways that waves interact with matter?

The Law of Reflection

- A line that is perpendicular to a surface is called the normal.
- The angle between the direction of the incoming wave and the normal is the angle of incidence.
- According to the law of reflection, the angle between the direction of the reflected wave and the normal is the angle of reflection.

According to the **law of reflection**, the angle of incidence equals the angle of reflection for all waves.



The Law of Reflection (cont.)

Science Use v. Common Use

normal

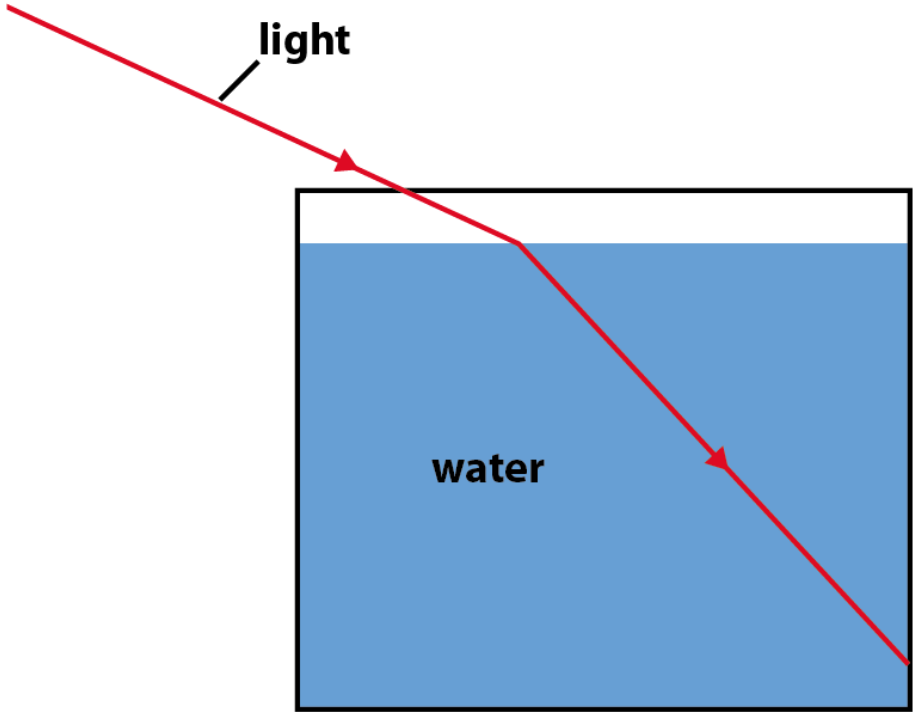
Science Use perpendicular to or forming a right angle with a line or plane

Common Use conforming to a standard or common

Refraction

- Sometimes waves change direction even if they are not reflected from a surface.
- **Refraction** occurs when a wave changes direction because its speed changes.
- The greater the change in speed, the more the wave changes direction.

The beam of light changes direction because light waves slow down as they move from air into water.



Refraction (cont.)

WORD ORIGIN

refraction

from Latin *refractus*, means "to break up"

Diffraction

- Waves can change direction as they travel by objects.
- The change in direction of a wave when it travels by the edge of an object or through an opening is called **diffraction**.
- The wavelengths of sound waves are similar in size to many common objects.

Diffraction (cont.)

KEY CONCEPT CHECK

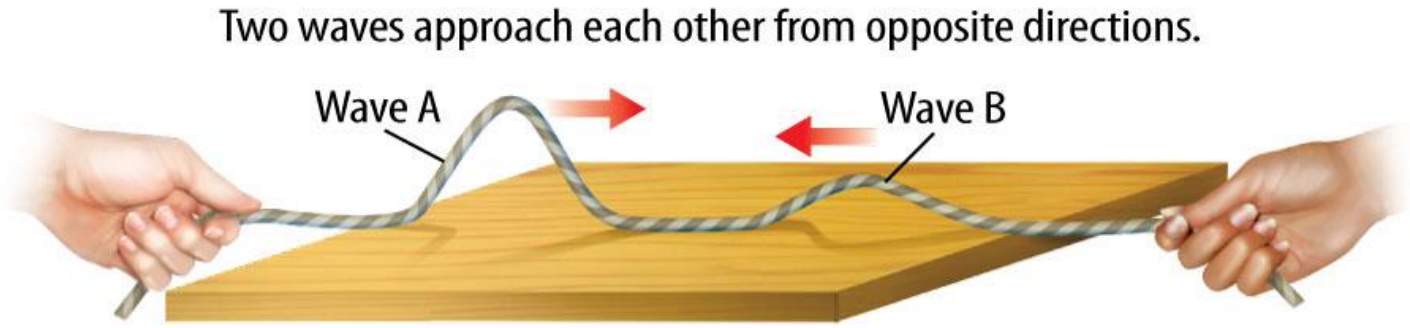
Compare and contrast reflection, refraction, and diffraction.

Interference

- In addition to interacting with matter, waves also interact with each other.
- **Interference** occurs when waves that overlap combine to form a new wave.
- After waves travel through each other, they keep moving without having been changed.

Wave Interference

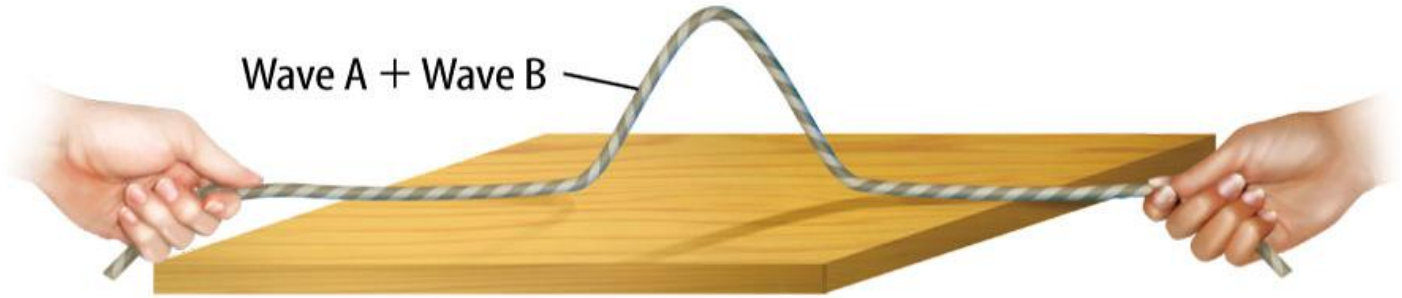
When waves interfere with each other, they create a new wave that has a different amplitude than either original wave.



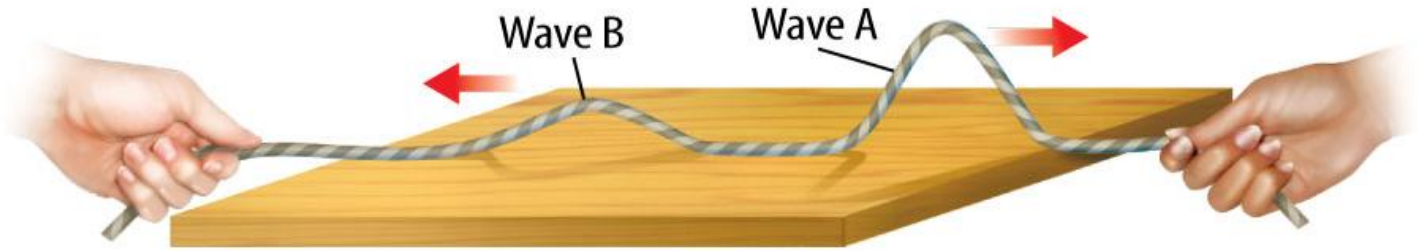
Get Animated

Wave Interference

The waves interfere with each other and form a large amplitude wave.



The waves keep traveling in opposite directions after they move through each other.

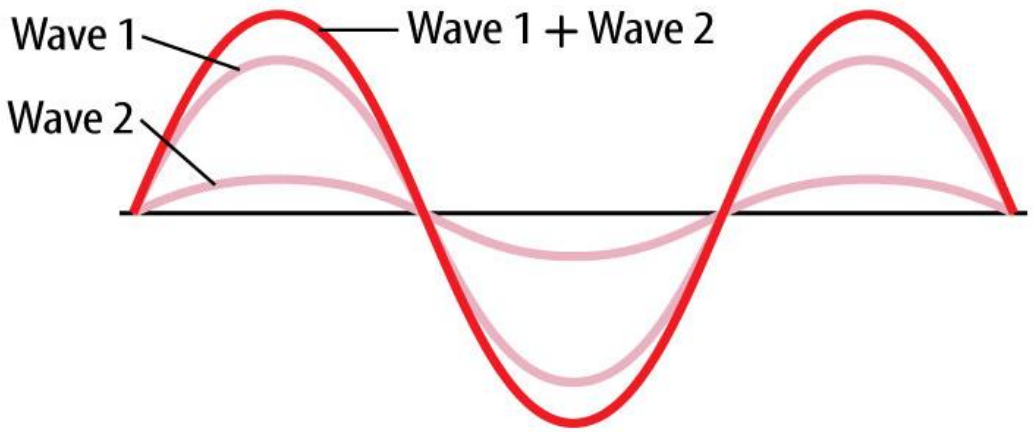


Interference (cont.)

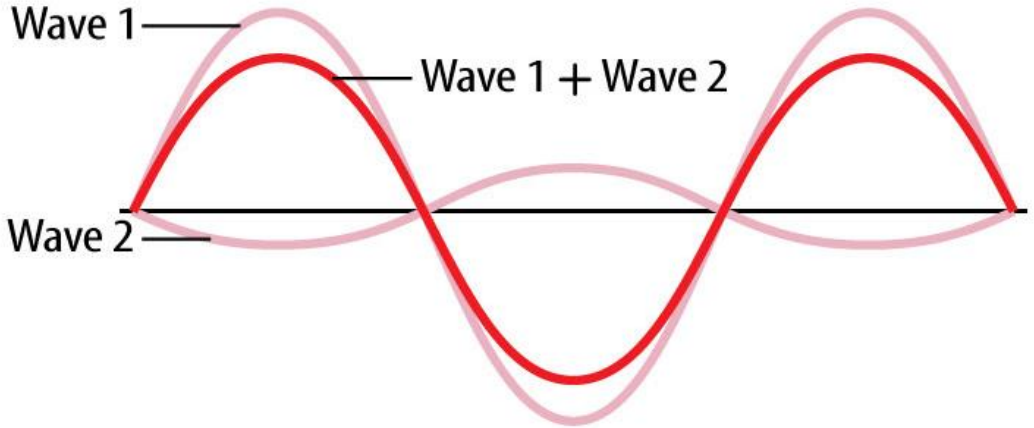
- As waves travel through each other, sometimes the crests of both waves overlap, forming a new wave with greater amplitude than either of the original waves.
- This type of interference is called constructive interference.

Interference (cont.)

- Destructive interference occurs when a crest of one wave overlaps the trough of another wave.
- The new wave that forms has a smaller amplitude than the sum of the amplitudes of the original waves.



Constructive Interference



Destructive Interference

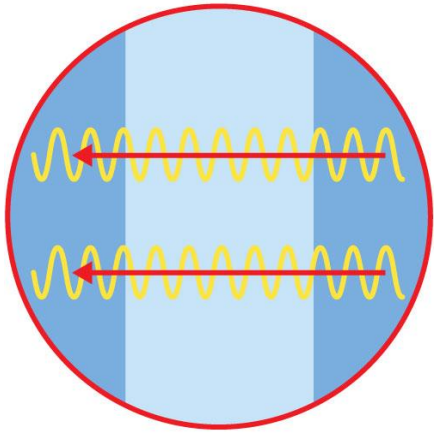
Interference (cont.)

KEY CONCEPT CHECK

Describe two types of wave interference.

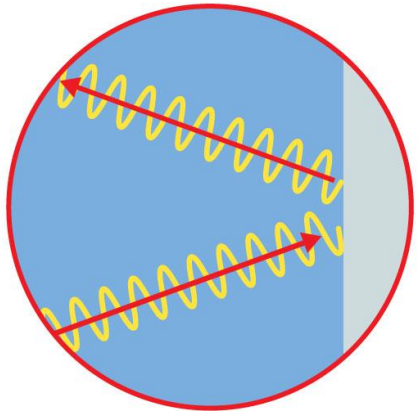
Summary

- Transmission occurs when waves travel through a material.



Summary

- Reflection occurs when waves bounce off the surface of a material.
- The change in direction of a wave when it travels through an opening is diffraction.



Lesson Review

Which occurs when a wave changes direction because its speed changes?

A. diffraction

B. interference

C. reflection

D. refraction

Lesson Review

Which occurs when waves that overlap combine to form a new wave?

A. diffraction

B. interference

C. reflection

D. refraction

Lesson Review

According to the law of reflection, the angle of incidence equals which of these?

A. the angle of refraction

B. the angle of reflection

C. the angle of interference

D. the angle of diffraction

Lesson Review

What do you think NOW?

Do you agree or disagree?

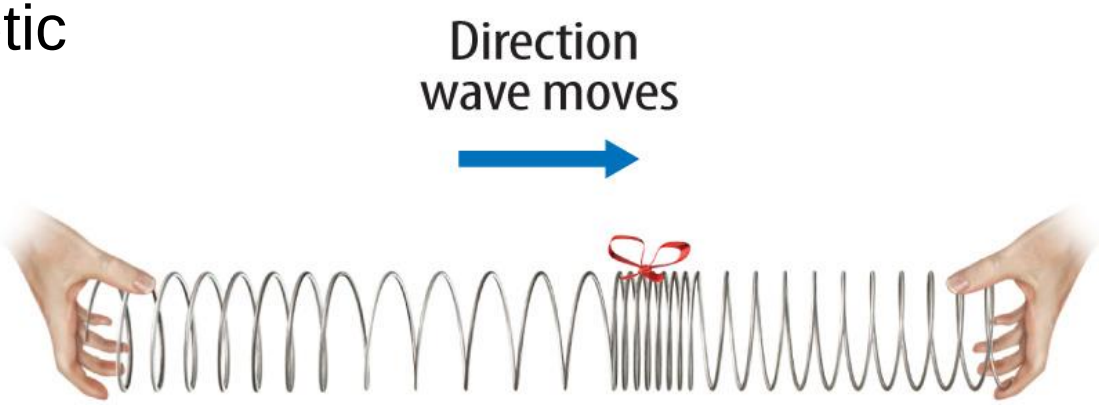
5. When light waves strike a mirror, they change direction.
6. Light waves travel at the same speed in all materials.

Menu

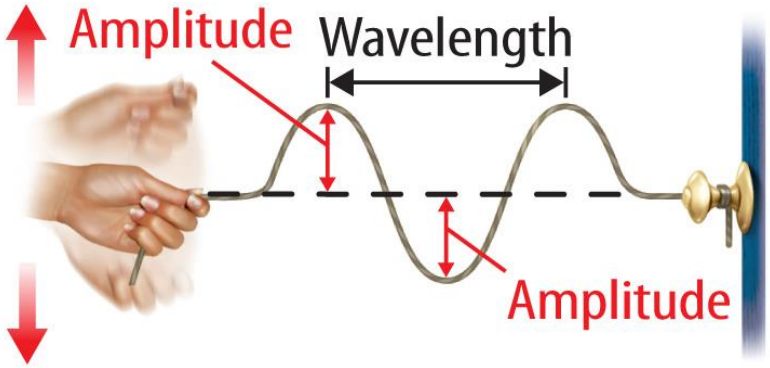
Waves transfer energy but not matter as they travel. Waves, such as light waves and sound waves, move at different speeds in different materials.

Lesson 1: What are waves?

- Vibrations cause waves.
- Transverse waves make particles in a medium move at right angles to the direction that the wave travels. Longitudinal waves make particles in a medium move parallel to the direction that the wave travels.
- Mechanical waves cannot move through a vacuum, but electromagnetic waves can.

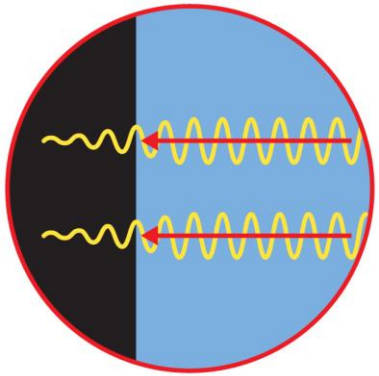


Lesson 2: Wave Properties



- All waves have the properties of amplitude, wavelength, and frequency.
- Increasing the frequency of a wave decreases the wavelength, and decreasing the frequency increases the wavelength.
- The speed of a wave depends on the type of material in which it is moving and the temperature of the material.

Lesson 3: Wave Interactions



- When waves interact with matter, absorption and transmission can occur.
- Waves change direction as they interact with matter when reflection, refraction, or diffraction occurs.
- Interference occurs while waves that overlap combine to form a new wave.

Chapter Review

Which type of wave makes particles in a medium move at right angles to the direction the wave travels?

A. longitudinal wave

B. mechanical wave

C. seismic wave

D. transverse wave

Chapter Review

Which term describes the back-and-forth or up-and-down movement of an object?

A. compressions

B. crests

C. troughs

D. vibrations

Chapter Review

Which describes the maximum distance the particles in a medium move from their rest position as the wave passes?

A. a wave's wavelength

B. a wave's speed

C. a wave's frequency

D. a wave's amplitude

Chapter Review

What happens to the particles in the compressions when the amplitude of a longitudinal wave increases?

A. They get closer together.

B. They get further apart.

C. They are unchanged.

D. They cannot be measured.

Chapter Review

Which occurs when energy carried by a wave transfers to the material in which it is traveling?

A. absorption

B. reflection

C. refraction

D. transmission

Standardized Test Practice

Which is the source of energy that produce all mechanical waves?

A. water

B. vibrating objects

C. troughs

D. crests

Standardized Test Practice

Which describes a material in which a mechanical wave travels?

A. crest

B. medium

C. rarefaction

D. trough

Standardized Test Practice

Every object gives off which of these?

A. electromagnetic waves

B. longitudinal waves

C. mechanical waves

D. transverse waves

Standardized Test Practice

Each vibration of an object produces which of these?

A. one compression

B. one rarefaction

C. one wavelength

D. two wavelengths

Standardized Test Practice

Which term refers to what happens when waves bounce off the surface of a material?

A. absorption

B. reflection

C. refraction

D. transmission