chapter 1 Waves

section 1 What are waves?

Before You Read

Describe what comes to mind when you think of waves.

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What You'll Learn

- how waves, energy, and matter are related
- the difference between transverse waves and compressional waves

Read to Learn

What is a wave?

Imagine that you are floating on an air mattress in a swimming pool and someone jumps into the pool near you. You and your air mattress bob up and down after the splash. What happened? Energy from the person jumping in made your air mattress move. But the person did not touch your air mattress. The energy from the person jumping in moved through the water in waves. <u>Waves</u> are regular disturbances that carry energy without carrying matter. The waves disturbed, or changed the motion of, your air mattress.

Study Coach

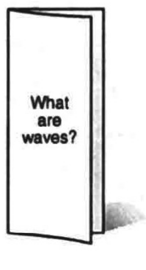
Create a Quiz As you read this section, write quiz questions based on what you have learned. After you write the quiz questions, answer them.

What do waves do?

Water waves carry energy. Sound waves also carry energy. Have you ever felt a clap of thunder? If so, you felt the energy in a sound wave. You also move energy when you throw a ball. But, there is a difference between a moving ball and a wave. A ball is made of matter. When you throw a ball, you move matter as well as energy. A wave moves only energy.

FOLDABLES™

A Identify Make the following Foldable from a sheet of notebook paper to help you organize information about waves.



A Model for Waves

How can a wave move energy without moving matter? Imagine several people standing in a line. Each person passes a ball to the next person. The ball moved, but the people did not. Think of the ball as the energy in a wave and the people as the molecules that move the energy.

Think it Over

1. **Recognize** Write two examples of a mechanical wave.

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Picture This

2. **Draw and Label** In the figure, draw a circle around each crest in the wave. Then, use a different color of pen or pencil to draw a square around each trough.

Mechanical Waves

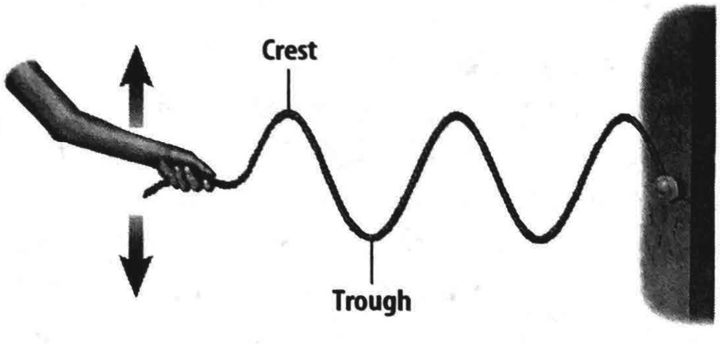
In the model of the wave, the ball (energy) could not be moved if the people (molecules) were not there. The same thing happens when a rock is thrown into a pond. Waves form where the rock hits the water. The molecules in the water bump into each other and pass the energy in the waves. The energy of a water wave cannot be moved or transferred if there are no water molecules.

Waves that use matter to move or transfer energy are **mechanical waves**. Water waves are mechanical waves. The matter that a mechanical wave travels through is called a medium. In a water wave, the medium is water. Solids, liquids, and gases are also mediums. For example, sound waves can travel through air, water, solids, and other gases. Without one of these mediums, there would be no sound waves. There is no air in outer space, so sound waves cannot travel in space.

What are transverse waves?

One kind of mechanical wave is a transverse wave. Transverse means to pass through, across, or over. In a **transverse wave**, the energy of the wave makes the medium move up and down or back and forth at right angles to the direction the wave moves. Think of a long rope stretched out on the ground. If you shake one end of the rope up and down, you make a wave that seems to slide along the rope, like the wave shown in the figure.

Transverse Wave



It might seem that the rope is moving away from you, but only the wave is moving away from your hand. The energy of the wave travels through the rope. But the matter in the rope does not move. Look at the figure. You can see that the wave has peaks and valleys that are spaced apart at even and regular distances. The high points of transverse waves are called crests. The low points are called troughs.

What are compressional waves?

Mechanical waves can be either transverse or compressional. Compress means to press or squeeze together. In a **compressional wave,** matter in the medium moves forward and backward along the same direction that the wave travels.

An example of a compressional wave made with a coiled spring is shown in the figure. A string is tied to the spring to show how the wave moves. Some coils on one end are compressed and then let go. As the wave begins, the coils near the end are close together. The other coils are far apart. The wave travels along the spring.

Compressional Wave

The coils and string move only as the wave passes them. Then, they go back to where they were. Compressional waves carry only energy forward along the spring. The spring is the medium the wave moves through, but the spring does not move along with the wave.

Sound Waves Sound waves are compressional waves. How do you make sound waves when you talk or sing? Hold your fingers against your throat while you hum. You can feel your vocal cords vibrating, or moving back and forth very quickly. You can also feel vibrations when you touch a stereo speaker while it is playing. All waves are made by something that is vibrating. ☑

Picture This

3. **Describe** Look at the figures. Describe the coils of the spring when the wave passes through them. Are they close together or far apart?

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Reading Check

4. **Identify** What kind of waves are sound waves?

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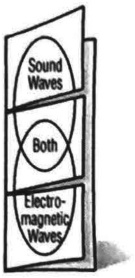
FOLDABLES™

B Compare and Contrast Make the following Foldable to compare and contrast the characteristics of sound waves and electromagnetic waves.



Picture This

5. **Identify** Look at the figure. What do the dots above the drum represent?

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Reading Check

6. **Classify** What is radiant energy?

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Making Sound Waves

A vibrating object causes the air molecules around it to vibrate. Look at the figure. When the drum is hit, the drumhead vibrates up and down. When the drumhead moves up, the air molecules next to it are pushed closer, or compressed, together. The group of compressed molecules is called a compression. The compression moves away from the drumhead.

When the drumhead moves down, the air molecules near it have more room and can spread apart. This group of molecules is a rarefaction. Rarefaction means something that has become less dense. The rarefaction also moves away from the drumhead. As the drumhead vibrates up and down, it makes a series of compressions and rarefactions in the air molecules that make up a sound wave.

Electromagnetic Waves

<u>Electromagnetic</u> (ih lek troh mag NEH tik) <u>waves</u> are waves that can travel through space where there is no matter. There are different kinds of electromagnetic waves, such as radio waves, infrared waves, visible light waves, ultraviolet waves, X rays, and gamma rays. These waves can travel in matter or in space. For example, radio waves from TV and radio stations travel through air. They can be reflected from a satellite in space. Then, they travel through air and the walls of your house to your TV or radio.

How does the Sun emit light and heat?

The Sun emits electromagnetic waves that travel through space and reach Earth. The energy carried by electromagnetic waves is called radiant energy. Almost 92 percent of the radiant energy that reaches Earth from the Sun is carried by infrared and visible light waves. Infrared waves make you feel warm. Visible light waves make it possible for you to see. Some of the Sun's radiant energy is carried by ultraviolet waves. These are the waves that can cause sunburn. ☑

● After You Read

Mini Glossary

compressional wave: a type of mechanical wave in which matter in the medium moves forward and backward along the same direction that the wave travels

electromagnetic waves: waves that can travel through space where there is no matter

mechanical waves: waves that use matter to move energy

transverse wave: a type of mechanical wave in which the energy of the wave makes the medium move up and down or back and forth at right angles to the direction the wave travels

waves: regular disturbances that carry energy without carrying matter

1. Read the key terms and definitions in the Mini Glossary above. Write a sentence using the term *mechanical wave* on the lines below.

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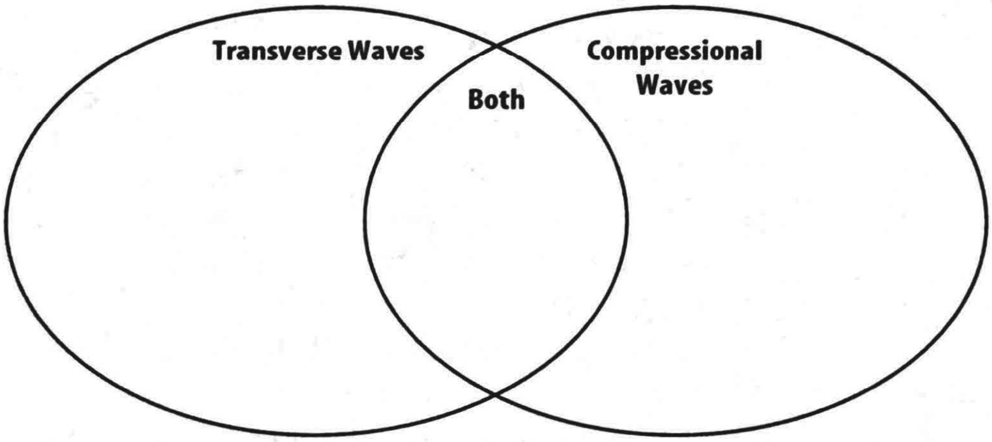
2. Use the Venn diagram to compare and contrast transverse and compressional waves. Arrange the characteristics of the waves according to whether they are true for transverse waves, compressional waves, or both.



3. How did the examples of the rope and the spring toy help you understand the difference between transverse and compressional waves?

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End of Section

chapter 1 Waves

section 2 Wave Properties

What You'll Learn

- about the frequency and the wavelength of a wave
- why waves travel at different speeds

Before You Read

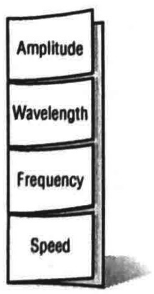
Think about waves in an ocean and waves in a pond. How would you describe each kind of wave?

Mark the Text

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

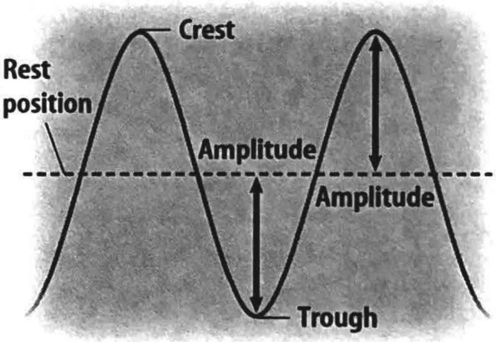
FOLDABLES™

C Organize Information Make the following Foldable to help you organize information about the different properties of waves.



Read to Learn

Amplitude

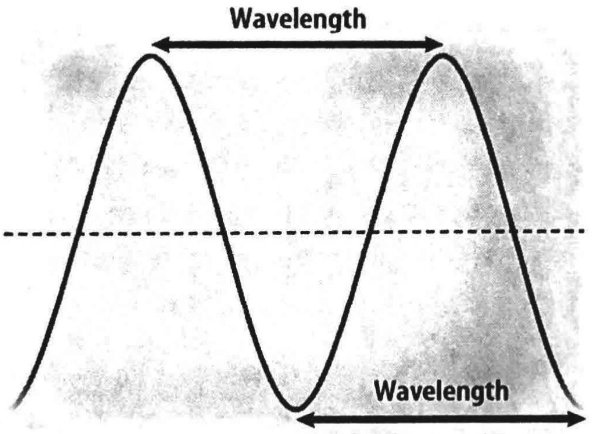


To describe a water wave, you might say how high the wave rises above, or falls below, a certain level. This distance is called the wave's amplitude. The **amplitude** of a transverse wave is one-half the distance between a crest and a trough, as shown in the figure.

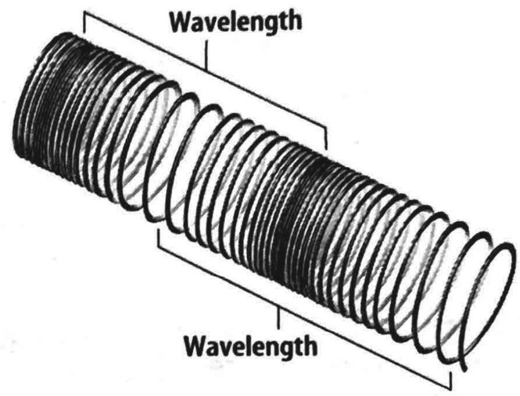
In a compressional wave, the amplitude depends on how close together the particles of the medium are. The amplitude is greater when the particles of the medium are squeezed closer together in each compression and spread farther apart in each rarefaction.

How are amplitude and energy related?

A wave's amplitude is related to the energy that the wave carries. For example, electromagnetic waves of bright light carry more energy and have greater amplitudes than electromagnetic waves of dim light. Loud sound waves carry more energy and have greater amplitudes than soft sound waves. A very loud sound can carry enough energy to damage your hearing.



Transverse Wave

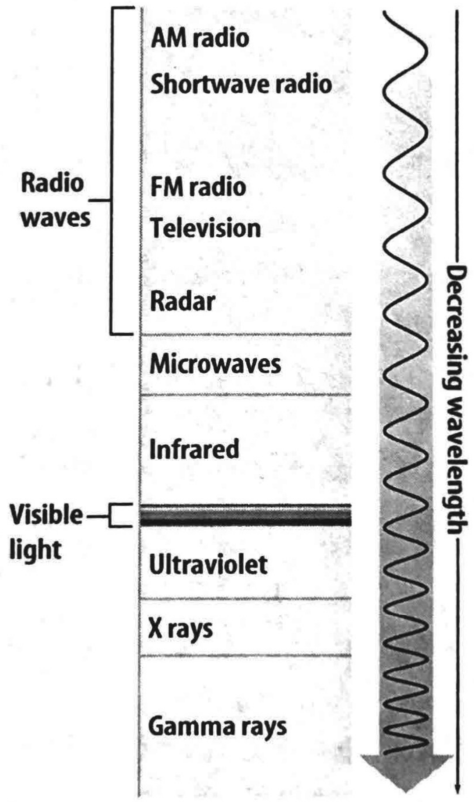


Compressional Wave

Wavelength

You also can describe a wave by its wavelength. Look at the figure above. For a transverse wave, **wavelength** is the distance from the top of one crest to the top of the next crest, or from the bottom of one trough to the bottom of the next trough. For a compressional wave, the wavelength is the distance between the center of one compression and the center of the next compression, or from the center of one rarefaction to the center of the next rarefaction.

The wavelengths of electromagnetic waves can vary from extremely short to longer than a kilometer. X rays and gamma rays have wavelengths that are smaller than the diameter of an atom.



This range of wavelengths is called the electromagnetic spectrum. The figure at the right shows the names given to different parts of the electromagnetic spectrum. Visible light, or light you can see, is only a small part of the electromagnetic spectrum. The wavelength of visible light gives light its color. For example, red light waves have longer wavelengths than green light waves.

Picture This

1. **Describe** Look at the figure of the transverse wave. Compare the wavelengths between two crests to the wavelength between two troughs. Describe what you find.

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Picture This

2. **Use Graphs** Which of the following has the greatest wavelength?
   a. microwaves
   b. X rays
   c. AM radio waves
   d. FM radio waves

Frequency

The frequency of a wave is the number of wavelengths that pass a given point in 1 s. Frequency is measured in hertz (Hz). Hertz are the number of wavelengths per second. So, 1 Hz means one wavelength per second. Remember that waves are made by something that vibrates. The faster the vibration is, the higher the frequency is of the wave. ☑

✔ Reading Check

3. **Summarize** Write the correct words to complete the sentence on the lines below.

   Waves that vibrate fast have ___a.___ frequencies. Waves that vibrate slowly have ___b.___ frequencies.

   a. ________________

   b. ________________

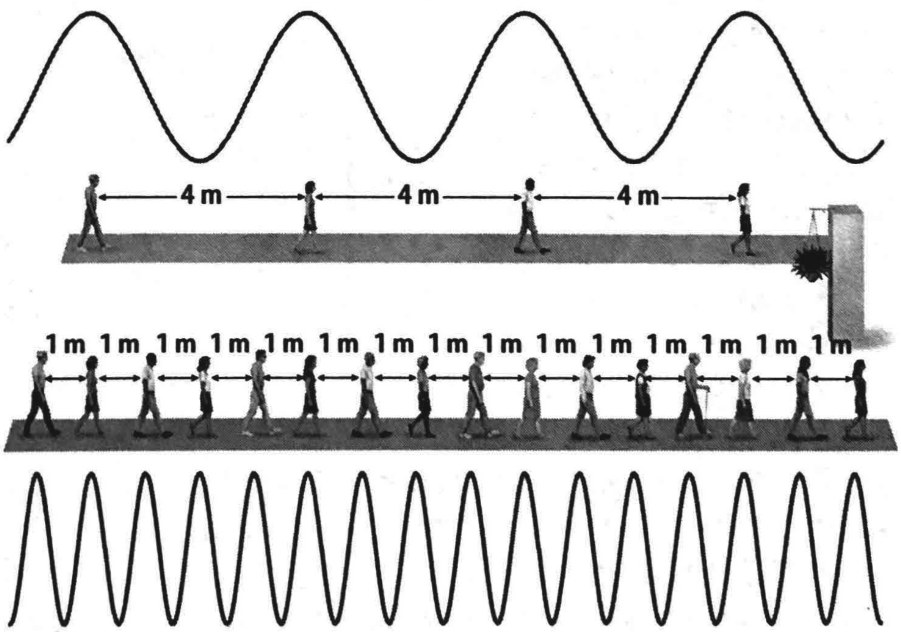
How can you model frequency?

You can use a model to help you understand frequency. If two waves travel with the same speed, their frequency and wavelength are related. Look at the figure below. Imagine people on two moving sidewalks next to each other. One sidewalk has four people on it. They are spaced 4 m apart. The other sidewalk has 16 people on it. They are spaced 1 m apart.

Imagine both sidewalks are moving at the same speed. The sidewalks move toward a pillar. On which sidewalk will more people go past the pillar? The sidewalk with 16 people on it has a shorter distance between people. Four people on this sidewalk will pass the pillar for every one person on the other sidewalk.

Picture This

4. **Use Models** On the bottom sidewalk, circle groups of four people each. Then draw a line from each group of four people to one person on the top sidewalk.



Applying Math

5. **Calculate** If three people on the top sidewalk pass the pillar, how many people on the bottom sidewalk will have passed the pillar?

   ____

How are frequency and wavelength related?

Suppose that each person on the sidewalks represents the crest of a transverse wave. The movement of the people on the first sidewalk is like a wave with a 4 m wavelength. For the second sidewalk, the wavelength would be 1 m.

The sidewalk with the longer, 4 m, wavelength carries a person past the pillar less frequently. Longer wavelengths have lower frequencies. On the second sidewalk, people pass the pillar more frequently. There, the wavelength is shorter—only 1 m. Shorter wavelengths have higher frequencies. This is true for all waves that travel at the same speed. As the frequency of a wave increases, its wavelength decreases.

What makes different colors and pitches?

The color of a light wave depends on the wavelength or the frequency of the light wave. For example, blue light has a higher frequency and shorter wavelength than red light.

Pitch is how high or how low a sound seems to be. Either the wavelength or the frequency determines the pitch of a sound wave. The pitch and frequency increase from note to note when you sing a musical scale. High-sounding pitches have higher frequencies. As the frequency of sound waves increases, their wavelengths decrease. Lower pitches have lower frequencies. As the frequency of a sound wave decreases, their wavelengths increase. ☑

Wave Speed

You have probably watched a thunderstorm on a hot summer day. You see lightning flash between a dark cloud and the ground. If the thunderstorm is far away, it takes many seconds before you will hear the sound of the thunder that goes with the lightning. This happens because light travels much faster in air than sound does. Light travels through air at about 300 million m/s. Sound travels through air at about 340 m/s. You can calculate the speed of any wave using this equation. The Greek letter lambda, λ, represents wavelength.

Wave Speed Equation

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

$$v = f\lambda$$

Mechanical waves, such as sound, and electromagnetic waves, such as light, change speed when they travel in different mediums. Mechanical waves usually travel fastest in solids and slowest in gases. Electromagnetic waves travel fastest in gases and slowest in solids. For example, the speed of light is about 30 percent faster in air than in water.

Reading Check

6. **Summarize** What determines color and pitch? Circle your answer.
   a. wavelength
   b. frequency
   c. wavelength and frequency
   d. wavelength or frequency

Applying Math

7. **Use an Equation** What is the speed in m/s of a wave with a frequency of 50 Hz and wavelength of 2 m? Show your work.

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After You Read

Mini Glossary

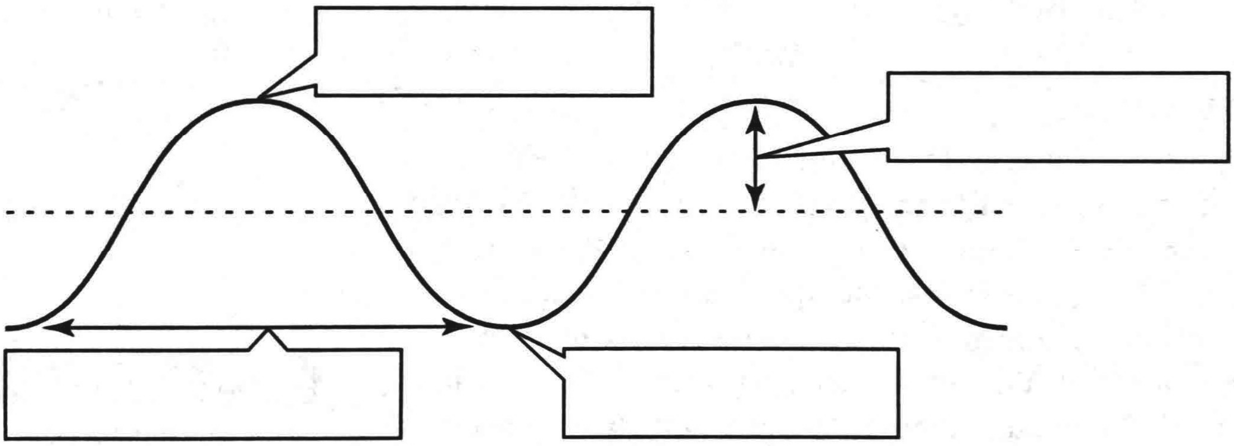
amplitude: transverse wave—one-half the distance between a crest and a trough; compressional wave—how close together the particles of the medium are

frequency: the number of wavelengths that pass a given point in 1 s

wavelength: transverse wave—the distance from the top of one crest to the top of the next crest, or from the bottom of one trough to the bottom of the next trough; compressional wave—the distance between the center of one compression and the center of the next compression, or from the center of one rarefaction to the center of the next rarefaction

1. Review the terms and their definitions in the Mini Glossary. Explain in your own words how wavelength and frequency are related.

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



3. You were asked to underline properties of waves and highlight information about them. How did this help you understand and learn about properties of waves?

End of Section

Science Online Visit **booko.msscience.com** to access your textbook, interactive games, and projects to help you learn more about properties of waves.

chapter 1

Waves

section 3 Wave Behavior

Before You Read

Have you ever shouted and heard an echo? On the lines below, write about what you think causes an echo.

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What You'll Learn

- how waves can reflect
- how waves change direction
- how waves can bend around barriers

Read to Learn

Reflection

You can see yourself in a mirror because waves of light are reflected. Reflect means to throw back. **Reflection** happens when a wave hits an object or surface and bounces off. Light waves from the Sun or a lightbulb bounce off of your face. The light waves hit the mirror and reflect back to your eyes. So you see your reflection in the mirror.

You can see your reflection in the smooth surface of a pond, too. But, if the water has ripples or waves, it is harder to see your reflection. You cannot see a sharp image when light reflects from an uneven surface like ripples on the water. This is because the reflected light goes in many different directions.

Refraction

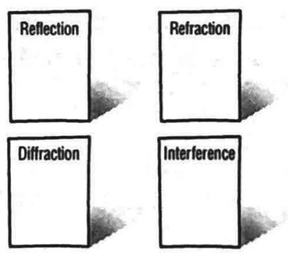
A wave changes direction when it reflects from a surface. Waves can also change direction in another way. Have you ever tried to grab a sinking object in a swimming pool, but missed it? You were probably sure you grabbed right where it was. But, the light waves from the object changed direction when they moved from the water to the air. The bending of a wave as it moves from one medium to another is **refraction**.

Mark the Text

Identify Details Highlight each question head. Then use another color to highlight the answer to each question.

FOLDABLES™

D Organize Information Use four quarter-sheets of paper to take notes about reflection, refraction, diffraction, and interference as you read.



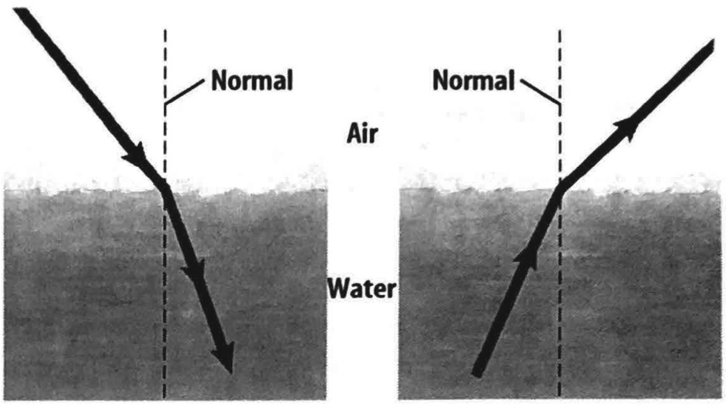
How are refraction and wave speed related?

Remember that the speed of a wave can be different in different materials. For example, light waves travel faster in air than in water. Refraction happens when the speed of a wave changes as it moves from one medium to another.

Picture This

1. Display In the water of the first figure, draw an arrow from the light ray to the normal that shows how the light ray bends toward the normal.

In the air of the second figure, draw an arrow from the normal to the light ray to show how the light ray bends away from the normal.



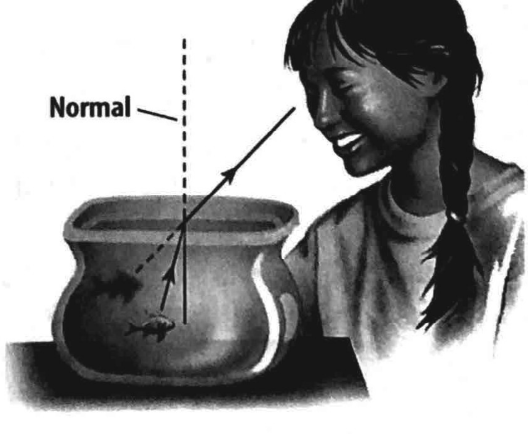
Wave Speed The figures above show how a light wave bends when it passes from air to water and water to air. A line that is perpendicular to the water's surface is called the normal. A light ray slows down and bends toward the normal when it passes from air into water. A light ray speeds up and bends away from the normal when it passes from water into air. If the speed of the wave changes a lot between mediums, the direction of the wave will change a lot too.

Refraction The figure below shows refraction of a fish in a fishbowl. Refraction makes the fish appear to be closer to the surface. It also appears farther away from you than it really is. Light rays reflected from the fish are bent away from the normal as they pass from water to air. Your brain assumes that light rays always travel in straight lines. So, the light rays seem to be coming from a fish that is closer to the surface.

Picture This

2. Use an Illustration In the figure, trace the line that shows how the light would travel if light rays did not travel at different speeds in water and air.

Refraction



How does refraction make color?

Recall that different wavelengths make different colors. You can separate the colors in sunlight using a prism. A prism is an object or medium used to break light into its different wavelengths. Light is refracted twice when it passes through a prism—once it when it enters and once when it leaves. Since each color has a different wavelength, each color is refracted by a different amount. The colors of light are separated when they leave the prism. Violet light has the shortest wavelength. It is refracted, or bent, the most. Red light has the longest wavelength. It is refracted the least.

How are the colors of a rainbow made?

Each raindrop is a tiny prism. Light rays refract when they enter and again when they leave a raindrop. The colors refract at different angles because they have different wavelengths. The wavelengths separate into all the colors you can see. The colors you see in a rainbow are in order of decreasing wavelength: red, orange, yellow, green, blue, indigo, and violet.

Diffraction

Why can you hear music from the band room when you are down the hall? Sound waves bend as they pass through an open doorway. This is why you can hear the music. This bending is caused by diffraction. **Diffraction** is the bending of waves around a barrier. ☑

Light waves can diffract, too. But, they cannot diffract as much as sound waves. You can hear the band playing music when you are down the hall, but you cannot see the musicians until you actually look inside the band room door.

How are diffraction and wavelength related?

The wavelengths of light are much shorter than the opening of the band room door. This is why the light waves do not diffract as much as the sound waves do when they pass through the door. Light waves have wavelengths that are very short—between about 400 and 700 billionths of a meter. The doorway is about 1 m wide. The wavelengths of sound waves you can hear can be as long as 10 m. Sound waves are much closer in measurement to the opening of the door. A wave diffracts more when its wavelength is similar to the size of the barrier or opening.

Think it Over

3. **Explain** why the color violet is refracted the most.

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Reading Check

4. **Define** What is diffraction?

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Think it Over

5. **Communicate** A garage door is 3 m wide. Which sound waves will diffract most easily when they pass through the door—ones with a wavelength of 2 m or ones with a wavelength of 0.2 m?

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Can water waves diffract?

Imagine water waves in the ocean. What happens when the waves hit a barrier like an island? They go around the island. If the wavelength of the water waves is close to the size and spacing between the islands, the water waves diffract around the islands and keep moving. If the islands are bigger than the wavelength of the water waves, the water waves diffract less.

What happens when waves meet?

Suppose you throw two pebbles into a still pond. Waves spread out from where each pebble hits the water. When two waves meet, will they hit each other and change direction? No, they pass right through each other and keep moving. ☑

Reading Check

6. **Infer** What happens when two waves meet?

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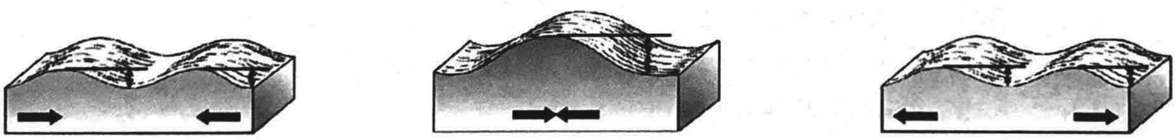
How do waves interfere with each other?

What happens when two waves overlap? The two waves add together, or combine, and make a new wave. The ability of two waves to combine and make a new wave when they overlap is **interference**. There are two kinds of interference—constructive and destructive as shown in the figure.

Constructive Interference In constructive interference, the crest of one wave overlaps the crest of another wave. They form a larger wave with greater amplitude. Then the original waves pass through each other and keep traveling as they were before.

Constructive Interference

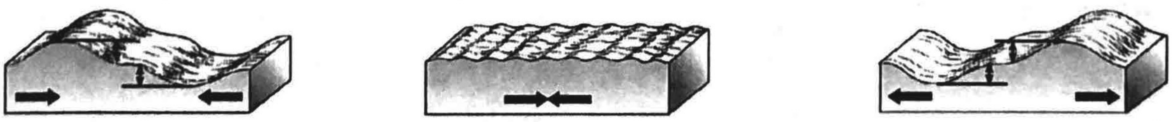


Picture This

7. **Conclude** Look at the figure of destructive interference. When can two waves cancel each other out?

Destructive Interference In destructive interference, the crest of one wave overlaps the trough of another. The amplitudes of the waves combine to make a wave with a smaller amplitude. If the waves have equal amplitudes, they will cancel each other out while the waves overlap. Then the original waves pass through each other and keep traveling as they were before.

Destructive Interference



How are particles and waves different?

Diffraction When light travels through a small opening, it spreads out in all directions on the other side of the opening. What would happen if particles were sent through the small opening? They would not spread out. They would keep going in a straight line. Diffraction, or spreading, happens only with waves.

Interference Interference does not happen with particles, either. When waves meet, they interfere and then keep going. If particles meet, either they hit each other and scatter, or miss each other. Interference and diffraction both are properties of waves but not particles. ☑

How can noise be reduced?

A lawn mower and a chain saw make loud noises. These loud noises can damage hearing.

Ear Protectors That Absorb Noise Loud sounds have waves with larger amplitudes than softer sounds. Loud sound waves carry more energy than softer sound waves. You have cells in your ears that vibrate and send signals to your brain. Energy from loud sound waves can damage these cells and can cause you to lose your hearing. Ear protectors can help prevent loss of hearing. The protectors absorb, or take in, some of the energy from sound waves. The ear is protected because less sound energy reaches it.

Ear Protectors That Interfere With Noise Pilots of small planes have a similar problem. The airplane's engine makes a lot of noise. But, pilots cannot wear ear protectors to shut out all of the engine's noise. If they did, they would not be able to hear instructions from air-traffic controllers.

Instead, pilots wear special ear protectors. These ear protectors have electronic circuits. The circuits detect noise from the airplane. Then they make sound frequencies that destructively interfere with the noise. Remember that destructive interference makes a smaller wave. The frequencies interfere only with the engine's noise. Pilots can still hear the air-traffic controllers. So, destructive interference can be helpful.

Reading Check

8. **Determine** What two properties do waves have that particles do not have?

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Think it Over

9. **Explain** How do the ear protectors some pilots wear work?

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● After You Read

Mini Glossary

diffraction: the bending of waves around a barrier

interference: the ability of two waves to combine and make a new wave when they overlap

reflection: occurs when a wave hits an object or surface and bounces off

refraction: the bending of a wave as it moves from one medium to another

1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences describing how refraction can make a rainbow.

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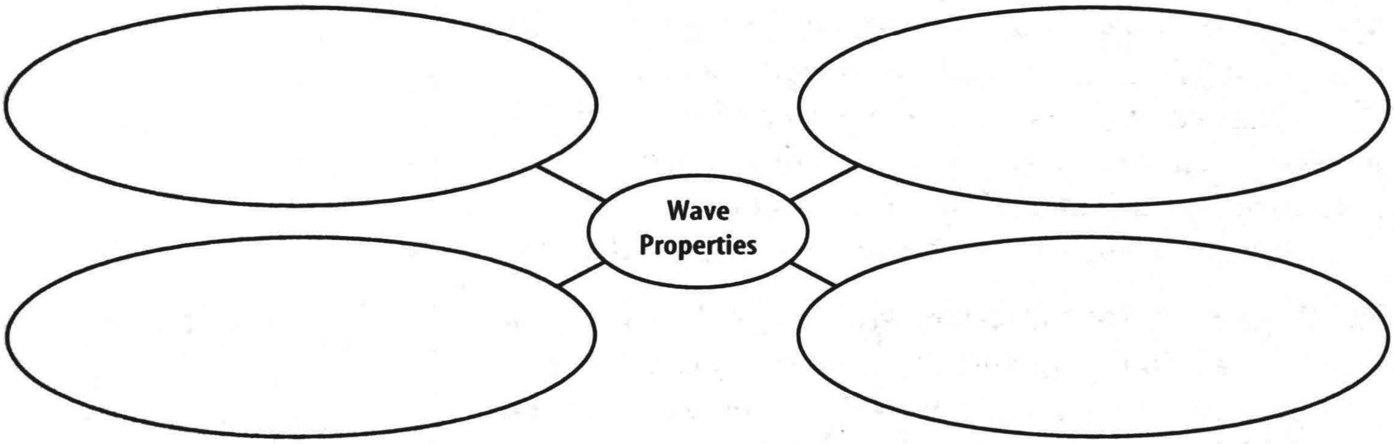
2. In the graphic organizer below, name the four different wave properties. Give an example of each.



3. You were asked to highlight each question head and the answer to each question as you read this section. Name another strategy that would help you learn the properties of wave.

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End of Section

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