



The **BIG** Idea

Sound and light are waves that transfer energy from one place to another.

SECTION 1

Waves

Main Idea Waves transfer energy outward from a vibrating object.

SECTION 2

Sound Waves

Main Idea Sound is a compressional wave that travels only through matter.

SECTION 3

Light

Main Idea Light waves are electromagnetic waves that travel in matter or space.

Waves, Sound, and Light

Ups and Downs

This wind surfer is riding high for now, but that will change soon. The energy carried by ocean waves makes this a thrilling ride, but other waves carry energy, too. Sound waves and light waves carry energy that enable you to hear and see the world around you.

Science Journal Write a short paragraph describing water waves you have seen.

Start-Up Activities



Wave Properties

If you drop a pebble into a pool of water, you notice how the water rises and falls as waves spread out in all directions. How could you describe the waves? In this lab you'll make a model of one type of wave. By describing the model, you'll learn about some properties of all waves.



1. Make a model of a wave by forming a piece of thick string about 50-cm long into a series of S shapes with an up and down pattern.
2. Compare the wave you made with those of other students. Notice how many peaks you have in your wave.
3. Reform your wave so that you have a different number of peaks.
4. **Think Critically** Write a description of your wave model. How did the distance between the peaks change as the number of peaks increased?



Preview this chapter's content and activities at blue.msscience.com

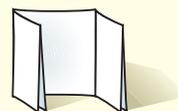
FOLDABLES™ Study Organizer

Waves Make the following Foldable to compare and contrast the characteristics of transverse and compressional waves.

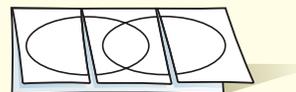
- STEP 1** Fold one sheet of lengthwise paper in half.



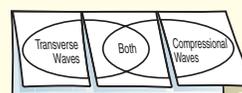
- STEP 2** Fold into thirds.



- STEP 3** Unfold and draw overlapping ovals. Cut the top sheet along the folds.



- STEP 4** Label the ovals as shown.



Construct a Venn Diagram As you read the chapter, list the characteristics unique to transverse waves under the left tab, those unique to compressional waves under the right tab, and those characteristics common to both under the middle tab.

Get Ready to Read

Make Connections

1 Learn It! Make connections between what you read and what you already know. Connections can be based on personal experiences (text-to-self), what you have read before (text-to-text), or events in other places (text-to-world).

As you read, ask connecting questions. Are you reminded of a personal experience? Have you read about the topic before? Did you think of a person, a place, or an event in another part of the world?

2 Practice It! Read the excerpt below and make connections to your own knowledge and experience.

What caused the loudest sound you ever heard?

According to the preceding section, what must an object do to produce waves?

How does a guitar player make a guitar produce sound?

How does the motion of a drummer's drumsticks produce sound waves? The impact of the sticks on the head of a drum causes the drum head to vibrate. These vibrations transfer energy to nearby air particles, producing sound waves in air. You can hear the sound because energy from the drums travels as sound waves to your ears. Every sound you hear is caused by something vibrating.

—from page 701

3 Apply It! As you read this chapter, choose five words or phrases that make a connection to something you already know.

Reading Tip

Make connections with memorable events, places, or people in your life. The better the connection, the more likely you will remember.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1 **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.

- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

2 **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.

- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

Before You Read A or D	Statement	After You Read A or D
	1 As the wavelength of light waves increases, the frequency also increases.	
	2 Loud sounds can permanently damage your ears.	
	3 The energy carried by a wave depends on the speed of the wave.	
	4 Different colors of light have different wavelengths.	
	5 Sound waves with a low frequency have a low pitch.	
	6 Waves transfer matter from one place to another.	
	7 Light cannot travel through empty space.	
	8 The human eye can detect waves in most of the electromagnetic spectrum.	
	9 Sound waves travel faster in warmer air than in cooler air.	
	10 Refraction occurs when waves change speed going from one material to another.	

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as you read

What You'll Learn

- **Explain** how waves transport energy.
- **Distinguish** among transverse, compressional, and electromagnetic waves.
- **Describe** the properties of waves.
- **Describe** reflection, refraction, and diffraction of waves.

Why It's Important

Devices such as televisions, radios, and cell phones receive and transmit information by waves.



Review Vocabulary

density: the mass per cubic meter of a substance

New Vocabulary

- wave
- transverse wave
- compressional wave
- wavelength
- frequency
- law of reflection
- refraction
- diffraction

What are waves?

When you float in the pool on a warm summer day, the up-and-down movement of the water tells you waves are moving past. Sometimes the waves are so strong they almost push you over. Other times, the waves just gently rock you. You know about water waves because you can see and feel their movement, but there are other types of waves, also. Different types of waves carry signals to televisions and radios. Sound and light waves move all around you and enable you to hear and see. Waves are even responsible for the damage caused by earthquakes.

Waves Carry Energy, not Matter A **wave** is a disturbance that moves through matter or space. Waves carry energy from one place to another. You can see that the waves in **Figure 1** carry energy by the way they crash against the rocks. In water waves, the energy is transferred by water molecules. When a wave moves, it may seem that the wave carries matter from place to place as the wave moves.

But that's not what really happens. When waves travel through solids, liquids, and gases, matter is not carried along with the waves. The movement of the fishing bob in **Figure 1** transfers energy to nearby water molecules. The energy is then passed from molecule to molecule as the wave spreads out. The wave disturbance moves outward, but the locations of the water molecules hardly change at all.

The energy carried by ocean waves can break rocks.



The movement of the fishing bob produces water waves that carry energy through the water.



Figure 1 Waves carry energy from place to place without carrying matter.



Types of Waves

Waves usually are produced by something moving back and forth, or vibrating. It is the energy of the vibrating object that waves carry outward. This energy can spread out from the vibrating object in different types of waves. Some waves, known as mechanical waves, can travel only through matter. Other waves called electromagnetic waves can travel either through matter or through empty space.

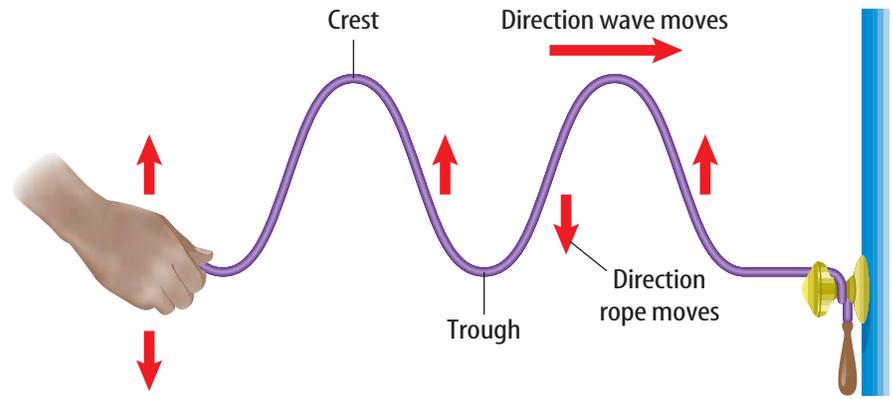


Figure 2 You make a transverse wave when you shake the end of a rope up and down.

Transverse Waves One type of mechanical wave is a transverse wave, shown in **Figure 2**. A **transverse wave** causes particles in matter to move back and forth at right angles to the direction in which the wave travels. If you tie a rope to a door handle and shake the end of the rope up and down, transverse waves travel through the rope.

High points in the wave are called crests. Low points are called troughs. The series of crests and troughs forms a transverse wave. The crests and troughs travel along the rope, but the particles in the rope move only up and down.

Compressional Waves Another type of mechanical wave is a compressional wave. **Figure 3** shows a compressional wave traveling along a spring coil. A **compressional wave** causes particles in matter to move back and forth along the same direction in which the wave travels.

In **Figure 3** the places where the coils are squeezed together are called compressions. The places where the coils are spread apart are called rarefactions. The series of compressions and rarefactions forms a compressional wave. The compressions and rarefactions travel along the spring, but the coils move only back and forth.

Reading Check

How does matter move in a compressional wave?

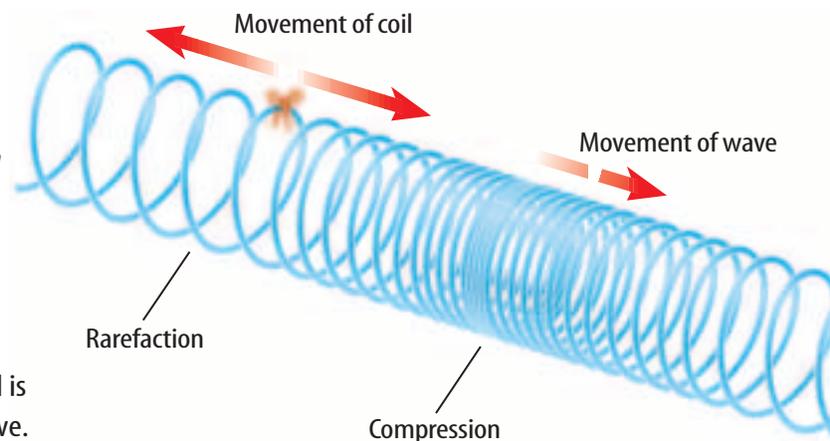


Figure 3 A wave on a spring coil is an example of a compressional wave.



Seismic waves move through the ground during an earthquake. Some of these waves are compressional, and others are transverse. The seismic waves that cause most damage to buildings are a kind of rolling waves. These rolling waves are a combination of compressional and transverse waves.

Electromagnetic Waves Light, radio waves, and X rays are examples of electromagnetic waves. Just like waves on a rope, electromagnetic waves are transverse waves. However, electromagnetic waves contain electric and magnetic parts that vibrate up and down perpendicular to the direction the wave travels.

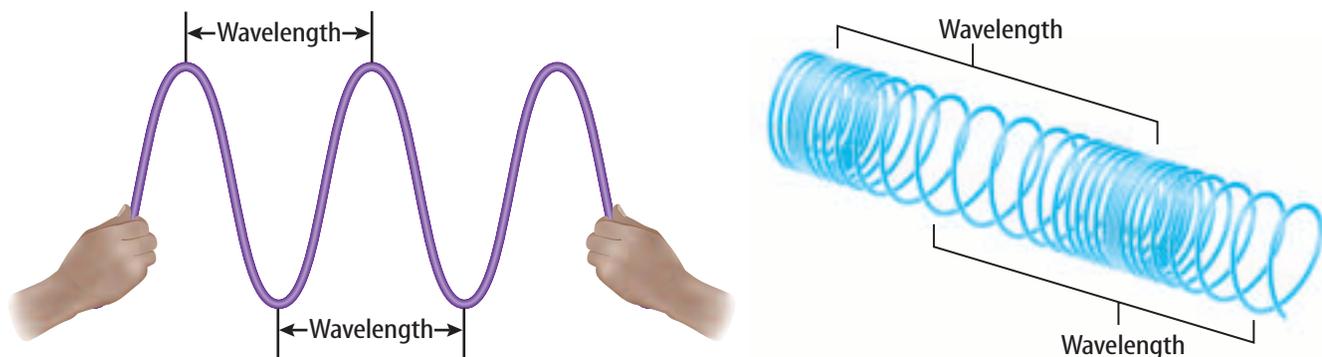
Properties of Waves

The properties that waves have depend on the vibrations that produce the waves. For example, if you move a pencil slowly up and down in a bowl of water, the waves produced by the pencil's motion will be small and spread apart. If you move the pencil rapidly, the waves will be larger and close together.

Wavelength The distance between one point on a wave and the nearest point moving with the same speed and direction is the **wavelength**. **Figure 4** shows how the wavelengths of transverse and compressional waves are measured. The wavelength of a transverse wave is the distance between two adjacent crests or two adjacent troughs. The wavelength of a compressional wave is the distance between two adjacent compressions or rarefactions.

Frequency The **frequency** of a wave is the number of wavelengths that pass by a point each second. If you were watching a transverse wave on a rope, the frequency of the wave would be the number of crests or troughs that pass you each second. In the same way, the frequency of a compressional wave is the number of compressions or rarefactions that would pass by each second.

Figure 4 The wavelength of a transverse wave is the distance from crest to crest or from trough to trough. The wavelength of a compressional wave is the distance from compression to compression or rarefaction to rarefaction.





Amplitude of a Transverse Wave

Waves have another property called amplitude. Suppose you shake the end of a rope by moving your hand up and down a large distance. Then you make a transverse wave with high crests and deep troughs. The wave you've made has a large amplitude. The amplitude of a transverse wave is half the distance between a crest and trough as shown in **Figure 5**. As the distance between crests and troughs increases, the amplitude of a transverse wave increases.

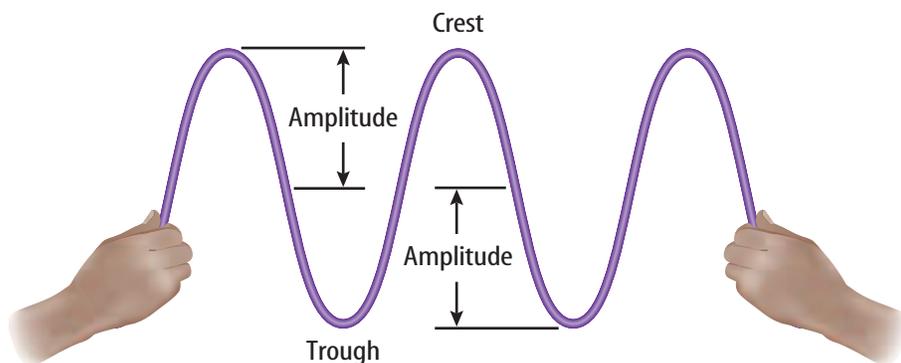


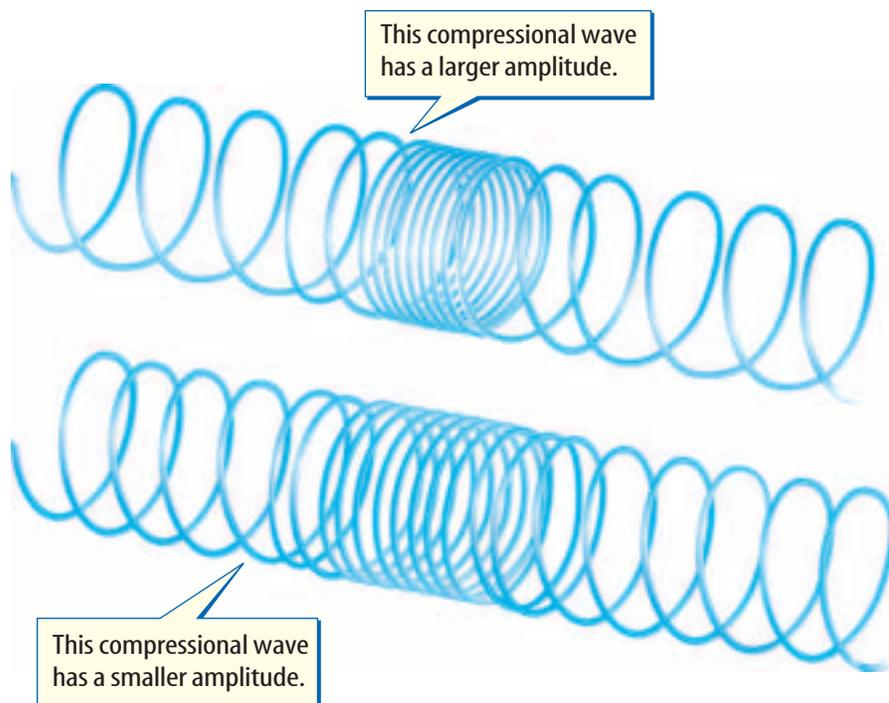
Figure 5 The amplitude of a transverse wave depends on the height of the crests or the depth of the troughs.

Amplitude of a Compressional Wave The amplitude of a compressional wave depends on the density of material in compressions and rarefactions as shown in **Figure 6**. Compressional waves with greater amplitude have compressions that are more squeezed together and rarefactions that are more spread apart. For example, in a spring, squeezing some coils together more tightly causes the nearby coils to be more spread apart.

Reading Check *What is the amplitude of a compressional wave?*

Amplitude and Energy The vibrations that produce a wave transfer energy to the wave. The more energy a wave carries, the larger its amplitude. By moving your hand up and down a larger distance in making a wave on a rope, you transfer more energy to the wave. Seismic waves are produced by vibrations in Earth's crust that cause earthquakes. The more energy these waves have, the larger their amplitudes and the more damage they cause as they travel along Earth's surface.

Figure 6 The amplitude of a compressional wave depends on the density of the material in the compressions and rarefactions.





Wave Speed The speed of a wave depends on the medium in which the wave travels. The faster waves travel, the more crests or compressions pass by you each second. You can calculate the speed of a wave if you know its wavelength and frequency using the equation below.

Wave Speed Equation

$$\text{wave speed (in m/s)} = \text{wavelength (in m)} \times \text{frequency (in Hz)}$$

$$v = \lambda f$$

In this equation, v is the symbol for wave speed and f is the symbol for frequency. The SI unit for frequency is the hertz, abbreviated Hz. One hertz equals one vibration per second, or one wavelength passing a point in one second. One hertz is equal to the unit 1/s. The wavelength is represented by the Greek letter lambda, λ , and is measured in meters.

Applying Math

Solve a Simple Equation

SPEED OF SOUND A sound wave produced by a lightning bolt has a frequency of 34 Hz and a wavelength of 10.0 m. What is the speed of the sound wave?

Solution

- This is what you know:*
 - wavelength: $\lambda = 10 \text{ m}$
 - frequency: $f = 34 \text{ Hz}$
- This is what you need to find:* wave speed: $v = ? \text{ m/s}$
- This is the procedure you need to use:*

Substitute the known values for wavelength and frequency into the wave speed equation and calculate the wave speed:

$$v = \lambda f = (10.0 \text{ m})(34 \text{ Hz})$$

$$= 340 \text{ m} \times \text{Hz} = 340 \text{ m} \times (1/\text{s}) = 340 \text{ m/s}$$
- Check your answer:* Divide your answer by the wavelength 10.0 m. The result should be the given frequency 34 Hz.

Practice Problems

- Waves on a string have a wavelength of 0.55 m. If the frequency of the waves is 6.0 Hz, what is the wave speed?
- If the frequency of a sound wave in water is 15,000 Hz, and the sound wave travels through water at a speed of 1,500 m/s, what is the wavelength?



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Waves Can Change Direction

Waves don't always travel in a straight line. When you look into a mirror, you use the mirror to make light waves change direction. Waves can change direction when they travel from one material to another. The waves can reflect (bounce off a surface), refract (change direction), or diffract (bend around an obstacle).

The Law of Reflection When waves reflect off a surface, they always obey the law of reflection, as shown in **Figure 7**. A line that makes an angle of 90 degrees with a surface is called the normal to the surface. According to **law of reflection**, the angle that the incoming wave makes with the normal equals the angle that the outgoing wave makes with the normal.

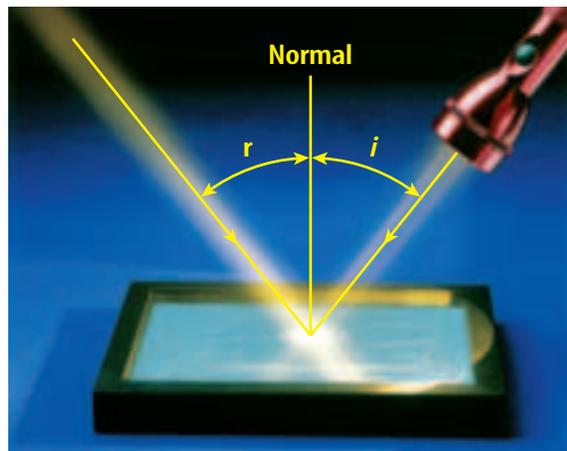
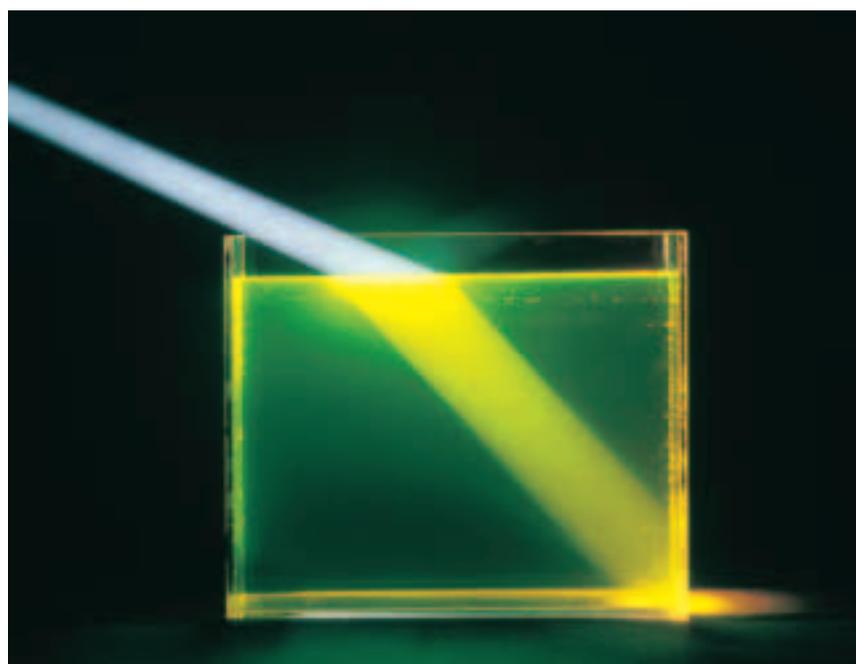


Figure 7 All waves obey the law of reflection. The angle of reflection, r , always equals the angle of incidence, i .

Refraction The speed of the wave depends on properties of the material through which it travels. A light wave, for example, travels faster through air than it does through water. **Figure 8** shows that a change in a wave's speed changes the direction in which the wave travels. When the light wave moves from air to water, it slows down. This change in speed causes the light wave to bend. **Refraction** is the change in direction of a wave when it changes speed as it travels from one material to another.

Figure 8 Refraction occurs when a wave changes speed. Light waves change direction when they slow down as they pass from air to water.



Mini LAB

Refraction of Light

Procedure

1. Fill a **drinking glass** about half full with water.
2. Place a **pencil** in the glass. Describe the appearance of the pencil.
3. Slowly add water to the glass. Describe how the appearance of the pencil changes.

Analysis

1. How does the appearance of the pencil depend on the level of water in the glass?
2. Where do the light waves coming from the pencil change speed?
3. **Infer** how the appearance of the pencil and the change in speed of the light waves are related.



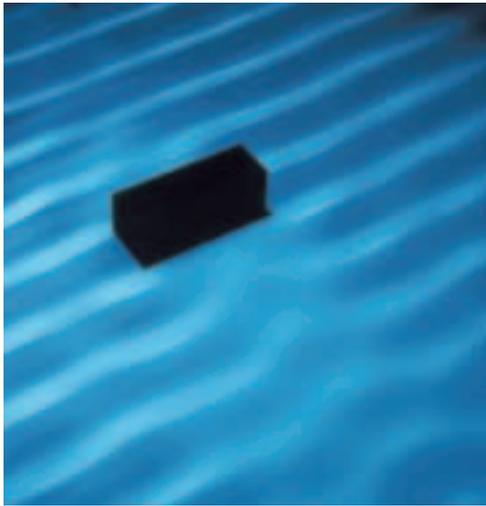


Figure 9 The amount of diffraction or bending around an obstacle depends on the size of the obstacle and the wavelength of the wave.

Diffraction Waves can change direction by **diffraction**, which is the bending of waves around an object. In **Figure 9**, the water waves are not completely blocked by the obstacle, but instead bend around the obstacle.

The amount of diffraction or bending of the wave depends on the size of the obstacle the wave encounters. If the size of the obstacle is much larger than the wavelength, very little diffraction occurs. Then there is a shadow behind the object where there are no waves.

As the wavelength increases compared with the size of the obstacle, the amount of diffraction increases. The amount of diffraction is greatest if the wavelength is much larger than the obstacle.

Diffraction of Sound and Light The wavelengths of sound waves are similar to the size of objects around you, but the wavelength of light waves are much shorter. As a result, you can hear people talking in a room with an open door even though you can't see them.

section 1 review

Summary

Wave Energy

- Waves transport energy without transporting matter.

Types of Waves

- Transverse waves cause particles in a material to move back and forth at right angles to the direction the waves travel.
- Compressional waves cause particles in a material to move back and forth along the same direction the waves travel.
- Electromagnetic waves are transverse waves that can travel through empty space.

Wave Properties

- A wave can be described by its wavelength, frequency, and amplitude.
- The energy carried by a wave increases as the amplitude of the wave increases.
- The speed of a wave, v , equals its wavelength, λ , multiplied by its frequency, f :
$$v = \lambda f$$
- Reflection, refraction, or diffraction can cause waves to change direction.

Self Check

- Analyze** How can waves transport energy without transporting matter from place to another?
- Explain** how the spacing between coils of a spring changes if the amplitude of compressional waves traveling along the spring increases.
- Predict** how the wavelength of waves traveling with the same speed would change if the frequency of the waves increases.
- Apply** Two similar-sized stones, one heavy and one light, are dropped from the same height into a pond. Explain why the impact of the heavy stone would produce waves with higher amplitude than the impact of the light stone would.
- Think Critically** Water waves produced by a speed boat strike a floating inner tube. Describe the motion of the inner tube as the waves pass by.

Applying Math

- Calculate Wave Speed** Find the speed of a wave with a wavelength of 0.2 m and a frequency of 1.5 Hz.
- Calculate Wavelength** Find the wavelength of a wave with a speed of 3.0 m/s and a frequency of 0.5 Hz.



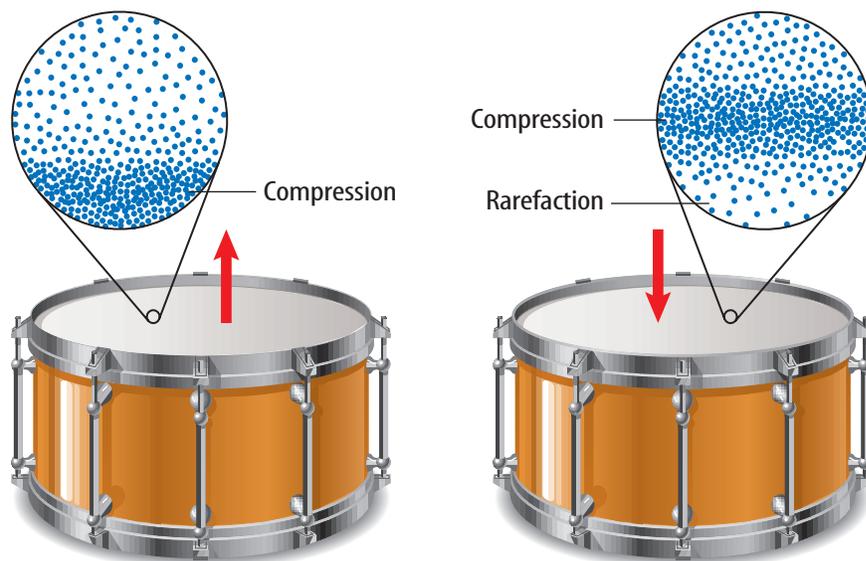
Sound Waves

Making Sound Waves

How does the motion of a drummer's drumsticks produce sound waves? The impact of the sticks on the head of a drum causes the drum head to vibrate. These vibrations transfer energy to nearby air particles, producing sound waves in air. You can hear the sound because energy from the drums travels as sound waves to your ears. Every sound you hear is caused by something vibrating. For example, when you talk, tissues in your throat vibrate in different ways to form sounds.

Sound Waves are Compressional Waves Sound waves produced by a vibrating object are compressional waves. **Figure 10** shows how the vibrating drum produces compressional waves. When the drummer hits the drum, the head of the drum vibrates. Nearby air particles vibrate with the same frequency as the frequency of vibrations. The drum head moving outward compresses nearby air particles. The drum head moving inward causes rarefactions in nearby air particles. The inward and outward movement of the drum head produces the same pattern of compressions and rarefactions in the air particles.

Sound waves can only travel through matter. The energy carried by a sound wave is transferred by the collisions between the particles in the material the wave is traveling in. A spaceship traveling outside Earth's atmosphere, for example, does not make any sound outside the ship.



as you read

What You'll Learn

- **Describe** how sound waves are produced.
- **Explain** how sound waves travel through matter.
- **Describe** the relationship between loudness and sound intensity.
- **Explain** how humans hear sound.

Why It's Important

A knowledge of sound helps you understand how to protect your hearing.

Review Vocabulary

perception: a recognition, sense, or understanding of something

New Vocabulary

- intensity
- pitch
- reverberation

Figure 10 A vibrating drum-head produces a sound wave. The drum head produces a compression each time it moves upward and a rarefaction each time it moves downward.



Table 1 Speed of Sound in Different Materials

Material	Speed (m/s)
Air (20°C)	343
Glass	5,640
Steel	5,940
Water (25°C)	1,493
Seawater (25°C)	1,533
Rubber	1,600
Diamond	12,000
Iron	5,130

Figure 11 The loudness of a sound depends on the amount of energy the sound waves carry.



Figure 12 The intensity of a sound wave decreases as the wave spreads out from the source of the sound. The energy the wave carries is spread over a larger area.

The Speed of Sound

Like all waves, the speed of sound depends on the matter through which it travels. Sound waves travel faster through solids and liquids. **Table 1** shows the speed of sound in different materials.

The speed of sound through a material increases as the temperature of the material increases. The effect of temperature is greatest in gases. For example, the speed of sound in air increases from about 330 m/s to about 350 m/s as the air temperature increases from 0° to 30°C.

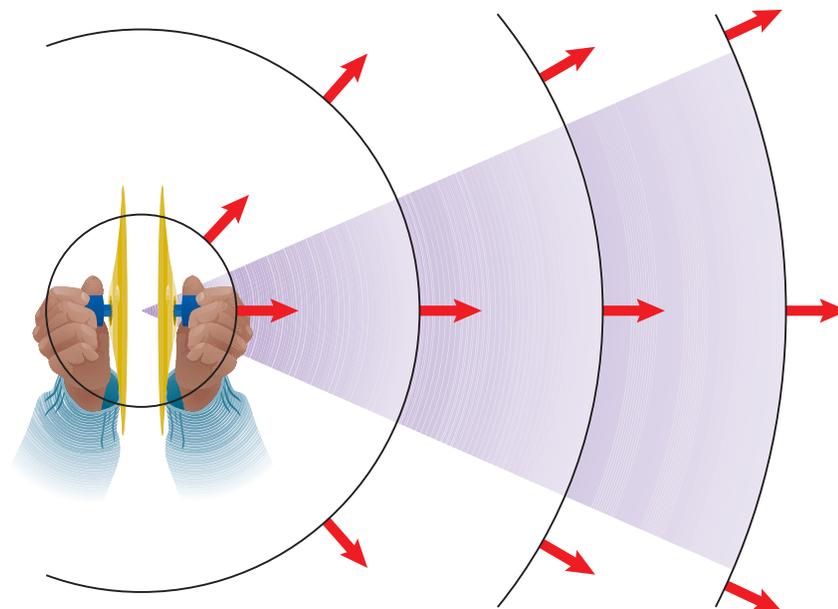


Reading Check How does temperature affect the speed of sound through a material?

The Loudness of Sound

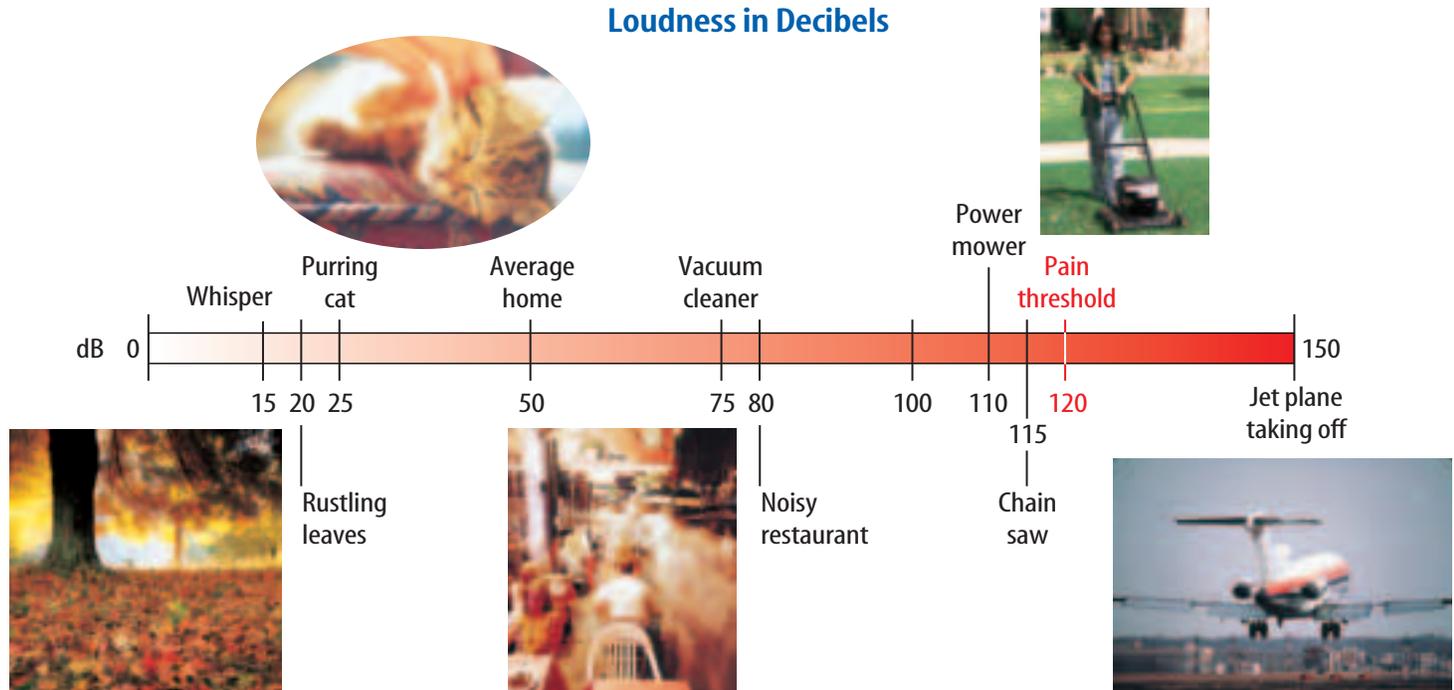
What makes a sound loud or soft? The girl in **Figure 11** can make a loud sound by clapping the cymbals together sharply. She can make a soft sound by clapping the cymbals together gently. The difference is the amount of energy the girl gives to the cymbals. Loud sounds have more energy than soft sounds.

Intensity The amount of energy that a wave carries past a certain area each second is the **intensity** of the sound. **Figure 12** shows how the intensity of sound from the cymbals decreases with distance. A person standing close when the girl claps the cymbals would hear an intense sound. The sound would be less intense for someone standing farther away. The intensity of sound waves is related to the amplitude. Sound with a greater amplitude also has a greater intensity.





Loudness in Decibels



The Decibel Scale and Loudness The intensity of sound waves is measured in units of decibels (dB), as shown in **Figure 13**. The softest sound a person can hear has an intensity of 0 dB. Normal conversation has an intensity of about 50 dB. Sound with intensities of about 120 dB or higher are painful to people.

Loudness is the human perception of the intensity of sound waves. Each increase of 10 dB in intensity multiplies the energy of the sound waves ten times. Most people perceive this as a doubling of the loudness of the sound. An intensity increase of 20 dB corresponds to a hundred times the energy and an increase in loudness of about four times.

Reading Check

How much has the energy of a sound wave changed if its intensity has increased by 30 dB?

Frequency and Pitch

The frequency of sound waves is determined by the frequency of the vibrations that produce the sound. Recall that wave frequency is measured in units of hertz (Hz), which is the number of vibrations each second. On the musical scale, the note C has a frequency of 262 Hz. The note E has a frequency of 330 Hz. People are usually able to hear sounds with frequencies between about 20 Hz and 20,000 Hz.

Pitch is the human perception of the frequency of sound. The sounds from a tuba have a low pitch and the sounds from a flute have a high pitch. Sounds with low frequencies have low pitch and sounds with high frequencies have high pitch.

Figure 13 The intensity of sound is measured on the decibel scale.

Infer how many times louder a power mower is compared to a noisy restaurant.

Hearing Damage
Prolonged exposure to sounds above 85 dB can damage your hearing. Research to find out the danger of noise levels you might experience at activities such as loud music concerts or basketball games.



Hearing and the Ear

The ear is a complex organ that can detect a wide range of sounds. You may think that the ear is just the structure that you see on the side of your head. However, the ear can be divided into three parts—the outer ear, the middle ear, and the inner ear. **Figure 14** shows the different parts of the human ear.

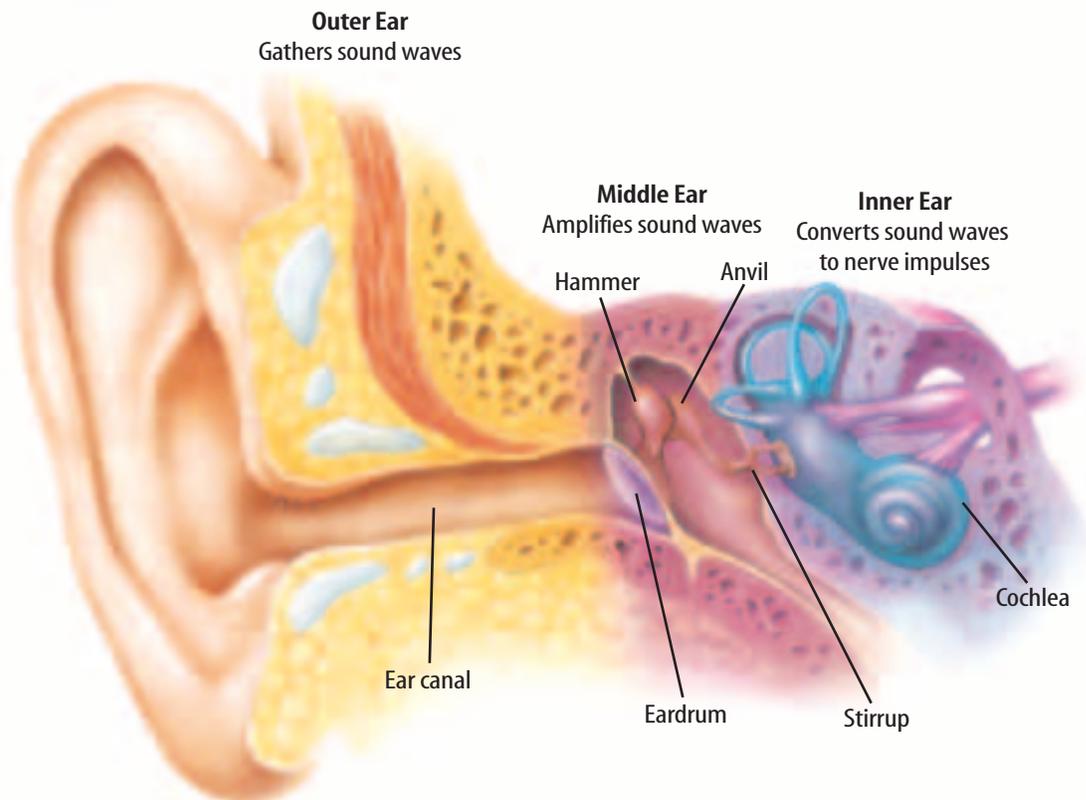
The Outer Ear The outer ear is a sound collector. It consists of the part that you can see and the ear canal. The visible part is shaped somewhat like a funnel. This shape helps the visible part collect sound waves and direct them into the ear canal.

The Middle Ear The middle ear is a sound amplifier. It consists of the ear drum and three tiny bones called the hammer, the anvil, and the stirrup. Sound waves that pass through the ear canal cause the eardrum to vibrate. These vibrations are transmitted to the three small bones, which amplify the vibrations.

The Inner Ear The inner ear contains the cochlea. The cochlea is filled with fluid and is lined with tiny hair-like cells. Vibrations of the stirrup bone are transmitted to the hair cells. The movement of the hair cells produce signals that travel to your brain, where they are interpreted as sound.



Figure 14 The human ear can be divided into three parts. The outer ear is the sound collector, the middle ear is the sound amplifier, and the inner ear is the sound interpreter.





The Reflection of Sound

Have you ever stood in an empty room and heard echoes when you talked very loudly? Echoes are sounds that reflect off surfaces. Repeated echoes are called **reverberation**. Concert halls and auditoriums are designed with soft materials on the ceilings and walls to avoid too much reverberation. Theaters like the one in **Figure 15** often have curtains on the walls because sounds won't reflect off soft surfaces. The curtains absorb the energy of the sound waves.

The reflection of sound can be used to locate or identify objects. Echolocation is the process of locating objects by bouncing sounds off them. Bats, dolphins, and other animals emit short, high-frequency sound waves toward a certain area. By interpreting the reflected waves, the animals can locate and determine properties of other animals. Doctors use reflection of sound waves in medicine. Computers can analyze ultrasonic waves that reflect off body parts to produce an internal picture of the body. These pictures help doctors monitor pregnancies, heart problems, and other medical conditions.

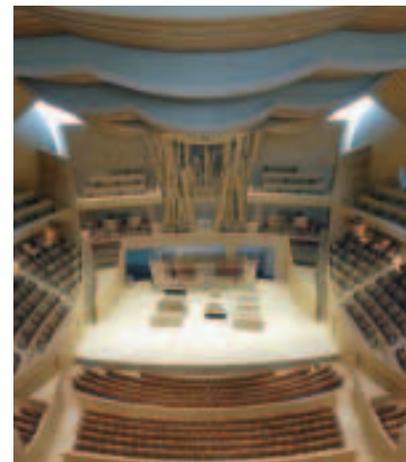


Figure 15 A modern concert hall contains materials that absorb sound waves to control reverberation and other sound reflections.

section 2 review

Summary

Making Sound Waves

- Sound waves are compressional waves produced by something vibrating.
- The speed of sound waves depends on the material in which the waves travel and its temperature.

Loudness and Pitch

- The intensity of a wave is the amount of energy the wave transports each second across a unit surface.
- The intensity of sound waves is measured in units of decibels.
- Loudness is the human perception of sound intensity.
- Pitch is the human perception of the frequency of a sound.

Hearing Sound

- You hear a sound when a sound wave reaches your ear and causes structures in your ear to vibrate.

Self Check

1. **Explain** why you hear a sound when you clap your hands together.
2. **Predict** whether sound would travel faster in air in the summer or in the winter.
3. **Compare and contrast** the sound waves produced by someone whispering and someone shouting.
4. **Describe** how vibrations produced in your ear by a sound wave enable you to hear the sound.
5. **Think Critically** Vibrations cause sounds, yet if you move your hand back and forth through the air, you don't hear a sound. Explain.

Applying Math

6. **Calculate a Ratio** How many times louder is a sound wave with an intensity of 50 dB than a sound wave with an intensity of 20 dB?
7. **Calculate Increase in Intensity** If the energy carried by a sound wave is multiplied by a thousand times, by what factor does the intensity of the sound wave increase?

Sound Waves in Matter

In this lab you can hear differences in sound when the sound waves travel through various materials.

Real-World Question

How does the movement of sound waves through different materials affect the sounds we hear?

Goals

- **Notice** the variations in sound when sound waves travel through different materials.
- **Infer** what property of the materials cause the sound waves to produce a different sound.

Materials

150-mL beakers (4) corn syrup
water pencil
vegetable oil

Safety Precautions



Procedure

1. Fill a beaker to the 140-mL line with water. Fill another beaker with 140 mL of vegetable oil. Fill a third beaker with 140 mL of corn syrup. Leave the fourth beaker empty.
2. Hold the pencil securely and tap the side of the beaker about halfway down from its rim. Use the metal band near the end of the pencil to make a clear sound.
3. Pay careful attention to the pitch of the sound. Notice whether the sound continues for a moment after the tap or if it stops suddenly. Write a description of the sound you hear in your data table.



4. Repeat steps 3 and 4 for the remaining beakers. You may wish to tap each beaker several times to be sure you hear the sound well.
5. **Compare** the sounds made by the beaker filled with air and the beaker filled with the different liquids.

Conclude and Apply

1. **List** the materials in the beakers in order of increasing density.
2. **Infer** how the pitch of the sound changes as the density of the material in the beaker increases.
3. How does the density of the material in the beaker affect how long the sound continued to be heard after the beaker was tapped?

Communicating Your Data

Compare your results with other students in your class.



Light

Waves in Empty Space

On a clear night you might see the Moon shining brightly, as in **Figure 16**. Like other waves, light waves can travel through matter, but light waves are different from water waves and sound waves. Light from the Moon has traveled through space that contains almost no matter. You can see light from the moon, distant stars, and galaxies because light is an electromagnetic wave. **Electromagnetic waves** are waves that can travel through matter or through empty space.

The Speed of Light Have you ever seen a movie where a spaceship travels faster than the speed of light? In reality, nothing travels faster than the speed of light. In empty space, light travels at a speed of about 300,000 km/s. Light travels so fast that light emitted from the Sun travels 150 million km to Earth in only about eight and a half minutes.

However, when light travels in matter, it interacts with the atoms and molecules in the material and slows down. As a result, light travels fastest in empty space, and travels slowest in solids. In glass, for example, light travels about 197,000 km/s.

Wavelength and Frequency of Light Can you guess how long a wavelength of light is? Wavelengths of light are usually expressed in units of nanometers (nm). One nanometer is equal to one billionth of a meter. For example, green light has a wavelength of about 500 nm, or 500 billionths of a meter. A light wave with this wavelength has a frequency of 600 trillion Hz.



as you read

What You'll Learn

- **Identify** the properties of light waves.
- **Describe** the electromagnetic spectrum.
- **Describe** the types of electromagnetic waves that travel from the Sun to Earth.
- **Explain** human vision and color perception.

Why It's Important

Light is necessary for vision. Other electromagnetic waves are used in devices such as cell phones and microwave ovens.

Review Vocabulary

spectrum: a range of values or properties

New Vocabulary

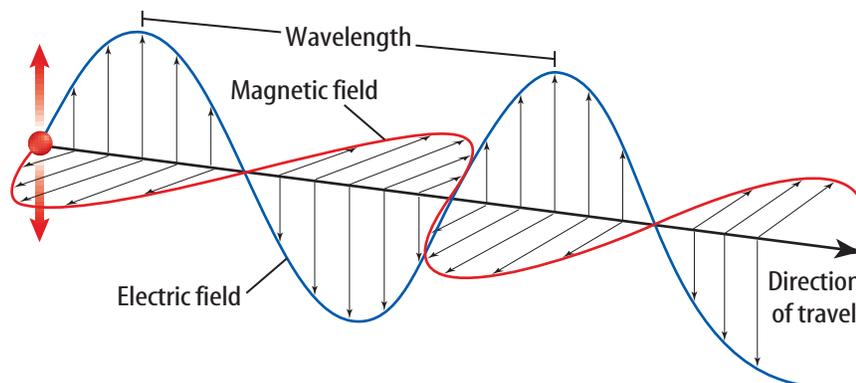
- electromagnetic waves
- electromagnetic spectrum
- infrared waves
- ultraviolet waves

Figure 16 The Moon reflects light from the Sun. These light waves travel through space to reach your eyes.

Infer whether a sound wave could travel from the Moon to Earth.



Figure 17 A light wave is a transverse wave that contains vibrating electric and magnetic fields. The fields vibrate at right angles to the direction the wave travels.



Properties of Light Waves

Light waves, and all electromagnetic waves, are transverse waves. Recall that a wave on a rope is a transverse wave that causes the rope to move at right angles to the direction the wave is traveling. An electromagnetic wave traveling through matter also can cause matter to move at right angles to the direction the wave is moving.

An electromagnetic wave contains an electric part and a magnetic part, as shown in **Figure 17**. Both parts are called fields and vibrate at right angles to the wave motion. The number of times the electric and magnetic parts vibrate each second is the frequency of the wave. The wavelength is the distance between the crests or troughs of the vibrating electric or magnetic parts.

Intensity of Light Waves The intensity of waves is a measure of the amount of energy that the waves carry. For light waves, the intensity determines the brightness of the light. A dim light has lower intensity because the waves carry less energy. However, as you move away from a light source, the energy spreads out and the intensity decreases.

 **Reading Check** What determines the intensity of light waves?

The Electromagnetic Spectrum

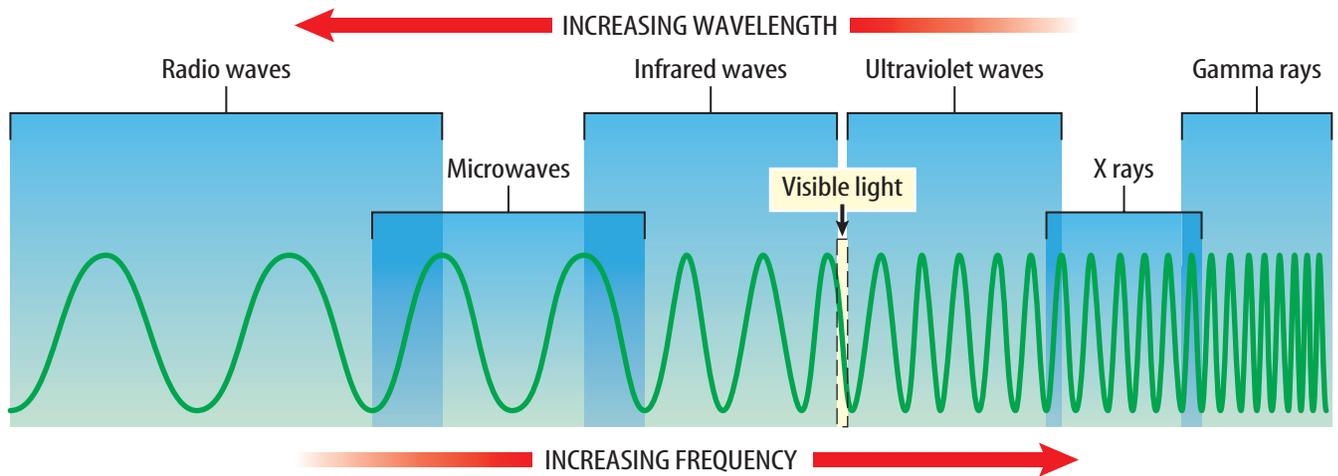
Light waves aren't the only kind of electromagnetic waves. In fact, there is an entire spectrum of electromagnetic waves, as shown in **Figure 18**. The **electromagnetic spectrum** is the complete range of electromagnetic wave frequencies and wavelengths. At one end of the spectrum the waves have low frequency, long wavelength, and low energy. At the other end of the spectrum the waves have high frequency, short wavelength, and high energy. All of the waves—from radio waves to visible light to gamma rays—are the same kind of waves. They differ from each other only by their frequencies, wavelengths, and energy.



Topic: Lasers

Visit blue.msscience.com for Web links to information about why the intensity of light emitted by lasers makes them useful.

Activity Write a short paragraph describing three uses for lasers.



Radio Waves and Microwaves The waves that carry radio and television signals to your home are radio waves. The wavelengths of radio waves are greater than about 0.3 meters. Some are even thousands of meters long. The shortest radio waves are called microwaves. These waves have a wavelength between about 0.3 meters and 0.001 meters. You use these waves when you cook food in a microwave oven. Microwaves are also used to transmit information to and from cell phones.

Infrared Waves When you use a remote control, infrared waves travel from the remote to a receiver on your television. **Infrared waves** have wavelengths between 0.001 meters and 700 billionths of a meter. All warm bodies emit infrared waves. Because of this, law enforcement officials and military personnel sometimes use special night goggles that are sensitive to infrared waves. These goggles can be used to help locate people in the dark.

Visible Light and Color The range of electromagnetic waves between 700 and 400 billionths of a meter is special, because that is the range of wavelengths people can see. Electromagnetic waves in this range are called visible light. **Figure 19** shows how different wavelengths correspond to different colors of light. White light, like the light from the Sun or a flashlight, is really a combination of different colors. You can see this by using a prism to separate white light into different colors. When the light passes through the prism, the different wavelengths of light are bent different amounts. Violet light is bent the most because it has the shortest wavelength. Red light is bent the least.

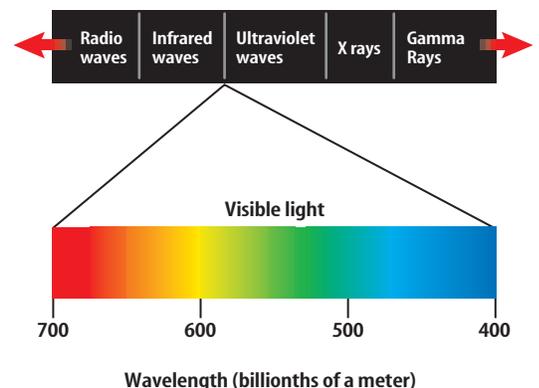
Reading Check *What range of wavelengths of electromagnetic waves can people see?*

Figure 18 Electromagnetic waves have a range of frequencies and wavelengths called the electromagnetic spectrum.

Infer *how the frequency of electromagnetic waves change as their wavelength decreases.*

Figure 19 Visible light waves are electromagnetic waves with a narrow range of wavelengths from about 700 to 400 billionths of a meter. The color of visible light waves depends on their wavelength.

Determine *the color of the visible light waves with the highest frequency.*





Mini LAB

Separating Wavelengths

Procedure

1. Place a **prism** in sunlight. Adjust its position until a color spectrum is produced.
2. Place the prism on a **desktop**. Dim the lights and shine a **flashlight** on the prism. Record your observations.
3. Shine a **laser pointer** on the prism. Record your observations.

WARNING: Do not shine the laser pointer into anyone's eyes.

Analysis

1. Determine whether sunlight and the light emitted from the flashlight contain light waves of more than one wavelength.
2. Determine whether the light emitted from the laser pointer contains light waves of more than one wavelength.

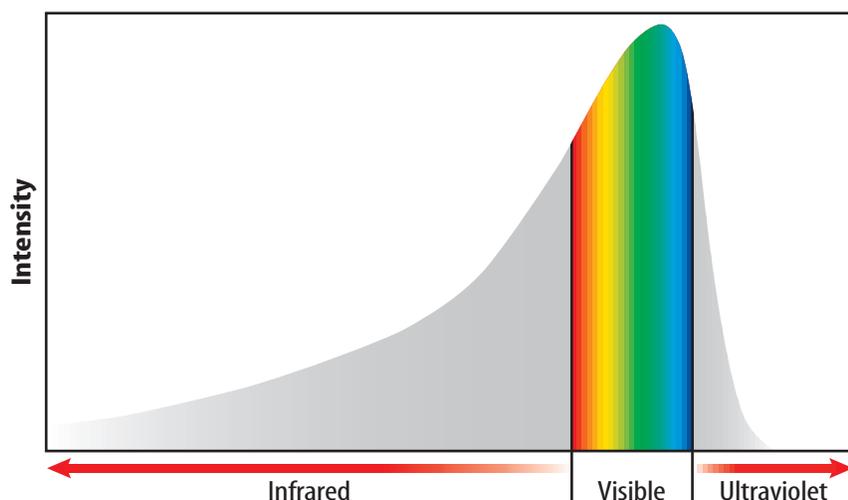
Figure 20 About 49 percent of the electromagnetic waves emitted by the Sun are infrared waves, about 43 percent are visible light, and about 7 percent are ultraviolet waves.

Ultraviolet Waves Electromagnetic waves with wavelengths between about 400 billionths and 10 billionths of a meter are **ultraviolet waves**. These wavelengths are shorter than those of visible light. Ultraviolet waves carry more energy than visible light waves. Sunlight that reaches Earth's surface contains a small fraction of ultraviolet waves. These waves can cause sunburn if skin is exposed to sunlight for too long. Excessive exposure to ultraviolet waves can permanently damage skin, and in some cases cause skin cancer. However, some exposure to ultraviolet waves is needed for your body to make vitamin D, which helps form healthy bones and teeth.

X Rays and Gamma Rays The electromagnetic waves with the highest energy, highest frequency, and shortest wavelengths are X rays and gamma rays. If you've ever broken a bone, the doctor probably took an X ray to examine the injured area. X rays are energetic enough to pass through the body. X rays pass through soft tissues, but are blocked by denser body parts, such as bones. This enables images to be made of internal body parts. Gamma rays are even more energetic than X rays. One use of gamma rays is in the food industry to kill bacteria that might increase the rate of spoilage of food.

Electromagnetic Waves from the Sun Most of the energy emitted by the Sun is in the form of ultraviolet, visible, and infrared waves, as shown in **Figure 20**. These waves carry energy away from the Sun and spread out in all directions. Only a tiny fraction of this energy reaches Earth. Most of the ultraviolet waves from the Sun are blocked by Earth's atmosphere. As a result, almost all energy from the Sun that reaches Earth's surface is carried by infrared and visible electromagnetic waves.

Electromagnetic Waves from the Sun



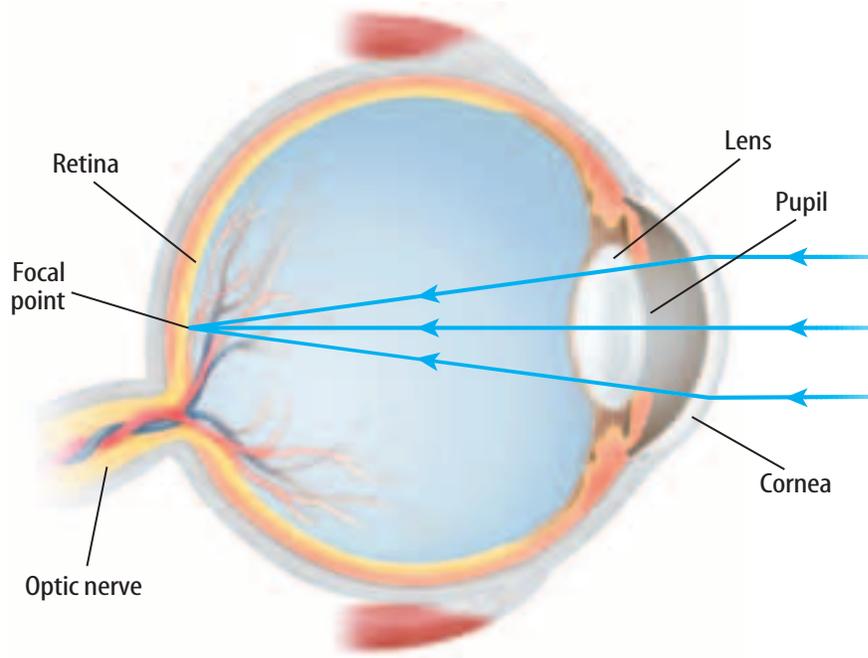


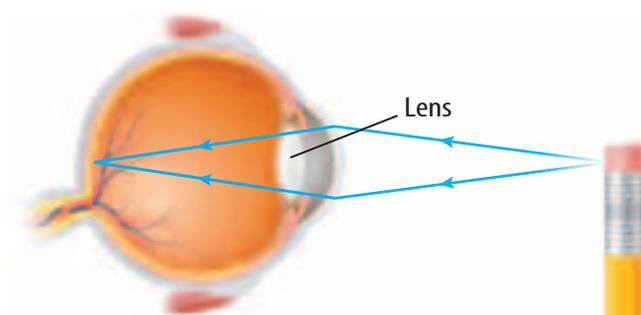
Figure 21 The cornea and the lens focus light waves that enter your eye so that a sharp image is formed on the retina. Special cells in the retina cause signals to be sent to the brain when they are struck by light.

The Eye and Seeing Light

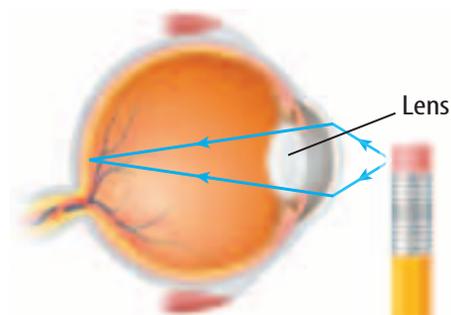
You see an object when light emitted or reflected from the object enters your eye, as shown in **Figure 21**. Light waves first pass through a transparent layer called the cornea (KOR nee uh), and then the transparent lens. The lens is flexible and changes shape to enable you to focus on objects that are nearby and far away, as shown in **Figure 22**. However, sometimes the eye is unable to form sharp images of both nearby and distant objects, as shown in **Figure 23** on the next page.

Why do objects have color? When light waves strike an object, some of the light waves are reflected. The wavelengths of the light waves that are reflected determine the object's color. For example, a red rose reflects light waves that have wavelengths in the red part of the visible spectrum. The color of objects that emit light is determined by the wavelengths of light that they emit. A neon sign appears to be red because it emits red light waves.

Figure 22 The shape of the lens changes when you focus on nearby and distant objects.



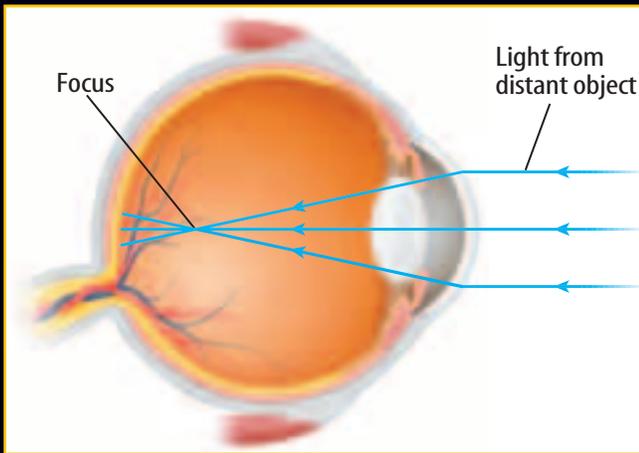
The lens becomes flatter when you focus on a distant object.



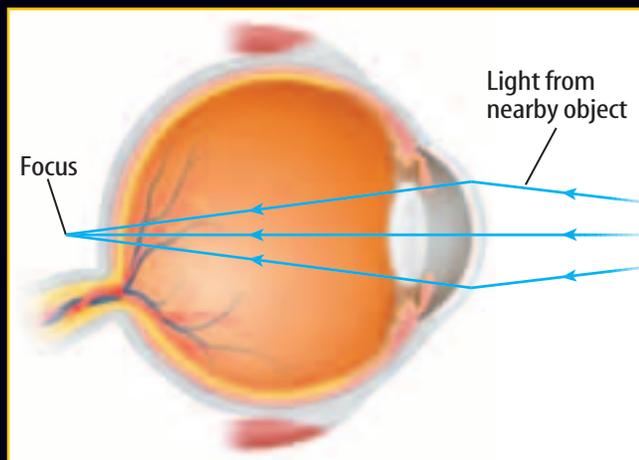
The lens becomes more curved when you focus on an object nearby.

Figure 23

In a human eye, light waves pass through the transparent cornea and the lens of the eye. The cornea and the lens cause light waves from an object to be focused on the retina, forming a sharp image. However, vision problems result when a sharp image is not formed on the retina. The two most common vision problems are farsightedness and nearsightedness.



◀ **Nearsightedness** A person that is nearsighted can see nearby objects clearly, but distant objects seem blurry. Nearsightedness results if the eyeball is too long, so that light waves from far away objects are brought to a focus before they reach the retina. This vision problem usually is corrected by wearing glasses or contact lenses. Laser surgery also is used to correct nearsightedness by reshaping the cornea.



◀ **Farsightedness** A farsighted person can see distant objects clearly, but cannot focus clearly on nearby objects. Farsightedness results if the eyeball is too short, so light waves from nearby objects have not been brought to a focus when they strike the retina.

▶ Farsightedness also can be corrected by wearing glasses. People commonly become farsighted as they get older because of changes in the lens of the eye. Laser surgery sometimes is used to correct farsightedness.



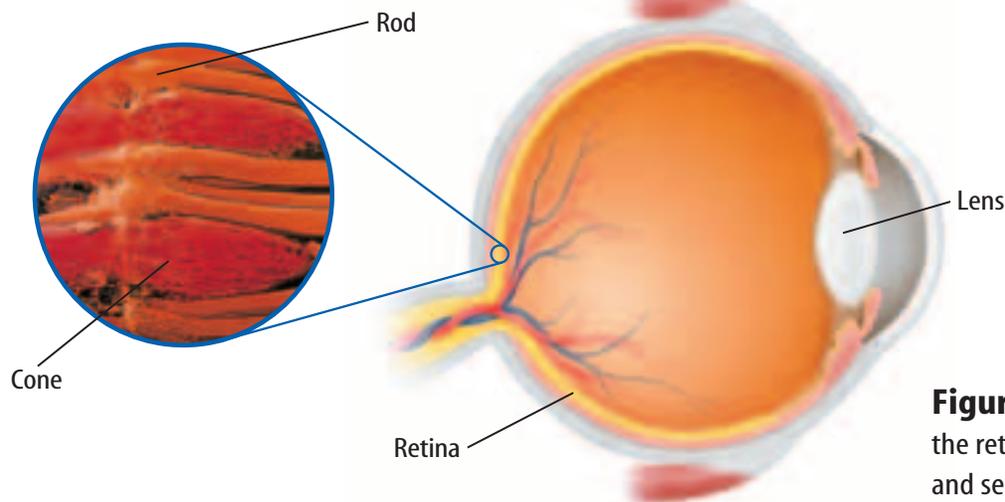


Figure 24 Rod and cone cells in the retina of the eye detect light and send signals to the brain.

Rod and Cone Cells The retina contains over a hundred million light-sensitive cells called rods and cones, shown in **Figure 24**. Rod cells are sensitive to dim light, and cone cells enable you to see colors. There are three types of cone cells. One type is sensitive to red and yellow light, another type is sensitive to green and yellow light, and the third type is sensitive to blue and violet light. The combination of the signals sent to the brain by all three types of cone cells forms the color image that you see.

section 3 review

Summary

Light and Electromagnetic Waves

- Light waves are electromagnetic waves. These waves travel through empty space at a speed of 300,000 km/s.
- Electromagnetic waves are transverse waves made of vibrating electric and magnetic fields.
- Radio waves, infrared waves, visible light, ultraviolet waves, X rays, and gamma rays form the electromagnetic spectrum.
- Most of the electromagnetic waves emitted by the Sun are infrared waves, visible light, and ultraviolet waves.

Color and Vision

- The color of an object is the color of the light the object emits or reflects.
- You see an object when light waves emitted or reflected by the object enter your eye and strike the retina.
- Rod cells and cone cells in the retina of the eye are light-sensitive cells that send signals to the brain when light strikes them.

Self Check

1. **Identify** the electromagnetic waves with the longest wavelengths and the electromagnetic waves with the shortest wavelengths.
2. **Describe** the difference between radio waves, visible light, and gamma rays.
3. **Compare and contrast** the rod cells and the cone cells in the retina of the human eye.
4. **Explain** why most of the electromagnetic waves emitted by the Sun that strike Earth's surface are infrared and visible light waves.
5. **Think Critically** Explain why the brightness of the light emitted by a flashlight decreases as the flashlight moves farther away from you.

Applying Skills

6. **Make a Concept Map** Design a concept map to show the sequence of events that occurs when you see a blue object.
7. **Recognize Cause and Effect** Why does light travel faster through empty space than it does through matter?

Bending Light

Goals

- **Compare and contrast** the reflection, refraction, and transmission of light.
- **Observe** how the refraction of white light can produce different colors of light.

Materials

small piece of cardboard
scissors
tape
flashlight
flat mirror
clear plastic CD case
250-mL beaker
prism

Safety Precautions



Real-World Question

What happens to light waves when they strike the boundary between two materials? Some of the light waves might be reflected from the boundary and some of the waves might travel into the second material. These light waves can change direction and be refracted in the second material. Transmission occurs when the light waves finally pass through the second material. What happens to light waves when they strike a boundary between air and other materials?

Procedure

1. Make a data table similar to the one shown below.

Bending of Light by Different Surfaces		
Surface	How Beam is Affected	Colors Formed
Mirror		
CD case	Do not write in this book.	
Water		
Prism		

2. Cut a slit about 3 cm long and 2 mm wide in a circular piece of cardboard. Tape the cardboard to the face of the flashlight.
3. In a darkened room, shine the flashlight at an angle toward the mirror. Determine whether the flashlight beam is reflected, refracted, or transmitted. Look at the color of the light beam after it strikes the mirror. Has the white light been changed into different colors of light? Record your observations on the chart.



Using Scientific Methods

Matt Meadows

4. Remove the clear plastic front from an empty CD case. Shine the flashlight at an angle toward the plastic. Does transmission occur? Record your observations about how the direction of the beam changes and colors of the light.
5. Fill the beaker with water. Shine the flashlight toward the side of the beaker so that the light shines through the water. Move the light beam from side to side. Record your observations.
6. Shine the flashlight toward a side of the prism. Move the light beam around until you see the outgoing beam spread into different colors. Record your observations.

Analyze Your Data

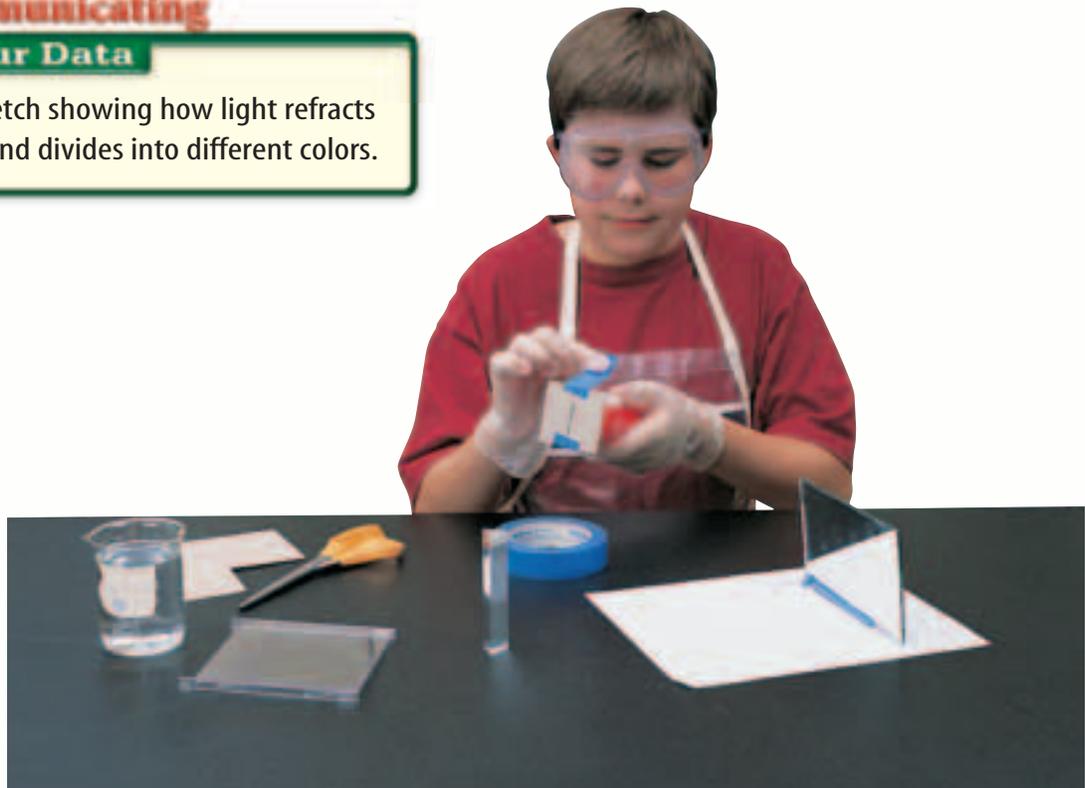
1. For which objects did reflection occur? For which objects did refraction occur? For which objects did transmission occur?
2. For which objects did refraction cause the flashlight beam to be separated into different colors?

Conclude and Apply

1. **Compare and contrast** the behavior of light waves when they strike the mirror and the CD case.
2. **Explain** why the beam that passes through the CD case does or does not change direction.
3. **Describe** how the light beam changes after it passes through the prism.

Communicating Your Data

Create a sketch showing how light refracts in a prism and divides into different colors.





Accidents in SCIENCE

**SOMETIMES
GREAT
DISCOVERIES
HAPPEN BY
ACCIDENT!**

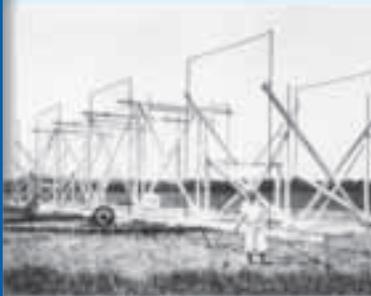
Jansky's Merry-Go-Round

Before the first radio signals were sent across the Atlantic Ocean in 1902, ships could only communicate if they could see one another. Being able to communicate using radio waves was a real breakthrough. But it wasn't without its problems—namely lots of static. Around 1930, Bell Labs was trying to improve radio communication by using radio waves with shorter wavelengths—between 10 and 20 m. They put Karl Jansky to work finding out what might be causing the static.



Karl Jansky built the first radiotelescope.

An Unexpected Discovery



This antenna built by Jansky detected radio waves from the Milky Way galaxy.

Jansky built an antenna to receive radio waves with a wavelength of about 14.5 m. He mounted it on a turntable so that he could rotate it in any direction. His coworkers called it “Jansky’s merry-go-round.”

After recording signals for several months, Jansky found that there were three types of static. Two were caused by nearby and distant thunderstorms.

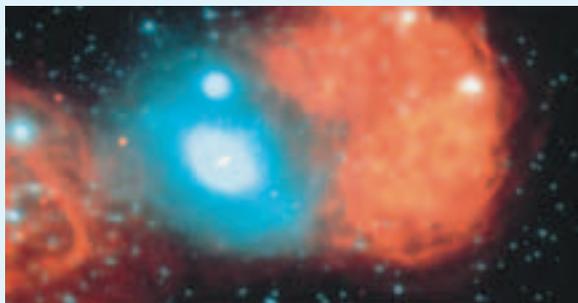
But the third was totally unexpected. It seemed to come from the center of our Milky Way galaxy! Jansky wanted to follow up on this unexpected discovery, but Bell Labs had the information it wanted. They were in the telephone business, not astronomy!

A New Branch of Astronomy

Fortunately, other scientists were fascinated with Jansky’s find. Grote Reber built a “radiotelescope” in his Illinois backyard. He confirmed Jansky’s discovery and did the first systematic survey of radio waves from space. The field of radioastronomy was born.

Previously, astronomers could observe distant galaxies only by gathering the light arriving from their stars. But they couldn’t see past the clouds of gas and small particles surrounding the galaxies. Radio waves emitted by a galaxy can penetrate much of the gas and dust in space. This allows radio astronomers to make images of galaxies and other objects they can’t see. As a result, Radio astronomy has revealed previously invisible objects such as quasars and pulsars.

The blue-white colors in this image are all you could see without radio waves.



Experiment Research how astronomers convert the radio waves received by radio telescopes into images of galaxies and stars.

Science online

For more information, visit blue.msscience.com/oops

Reviewing Main Ideas

Section 1 Waves

1. Waves carry energy from place to place without transporting matter.
2. Transverse waves move particles in matter at right angles to the direction in which the waves travel.
3. Compressional waves move particles back and forth along the same direction in which the waves travel.
4. The speed of a wave equals its wavelength multiplied by its frequency.

Section 2 Sound Waves

1. Sound waves are compressional waves produced by something vibrating.

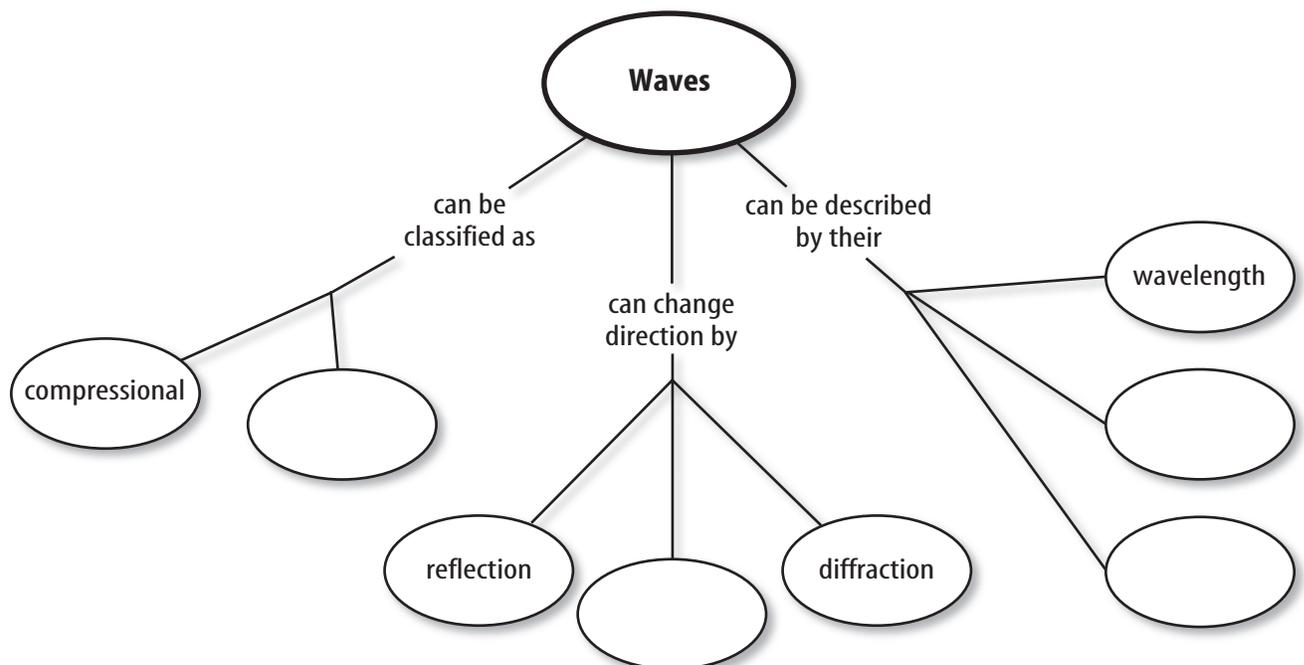
2. The intensity of sound waves is measured in units of decibels.
3. You hear sound when sound waves reach your ear and cause parts of the ear to vibrate.

Section 3 Electromagnetic Waves and Light

1. Electromagnetic waves are transverse waves that can travel in matter or empty space.
2. Light waves are electromagnetic waves.
3. The range of frequencies and wavelengths of electromagnetic waves forms the electromagnetic spectrum.
4. You see an object when light waves emitted or reflected by the object enter your eye and strike light-sensitive cells inside the eye.

Visualizing Main Ideas

Copy and complete the following concept map on waves.



Using Vocabulary

compressional wave p.695	law of reflection p.699
diffraction p.700	pitch p.703
electromagnetic spectrum p.708	refraction p.699
electromagnetic waves p.707	reverberation p.705
frequency p.696	transverse wave p.695
infrared waves p.709	ultraviolet waves p.710
intensity p.702	wave p.694
	wavelength p.696

Complete each statement using a word(s) from the vocabulary list above.

- The bending of a wave when it moves from one material into another is _____.
- The bending of waves around an object is due to _____.
- The _____ is the complete range of electromagnetic wave frequencies and wavelengths.
- The amount of energy that a wave carries past a certain area each second is the _____.
- In a(n) _____, the particles in the material move at right angles to the direction the wave moves.
- The _____ of a wave is the number of wavelengths that pass a point each second.
- In a _____, particles in the material move back and forth along the direction of wave motion.
- Which of the following are units for measuring frequency?
A) decibels **C)** meters
B) hertz **D)** meters/second
- Through which of these materials does sound travel fastest?
A) empty space **C)** steel
B) water **D)** air
- An increase in a sound's pitch corresponds to an increase in what other property?
A) intensity **C)** wavelength
B) frequency **D)** loudness
- Soft materials are sometimes used in concert halls to prevent what effect?
A) refraction **C)** compression
B) diffraction **D)** reverberation
- Which of the following are not transverse waves?
A) radio waves **C)** sound waves
B) infrared waves **D)** visible light
- Which of the following wave properties determines the energy carried by a wave?
A) amplitude **C)** wavelength
B) frequency **D)** wave speed
- Which of the following best describes why refraction of a wave occurs when the wave travels from one material into another?
A) The wavelength increases.
B) The speed of the wave changes.
C) The amplitude increases.
D) The frequency decreases.

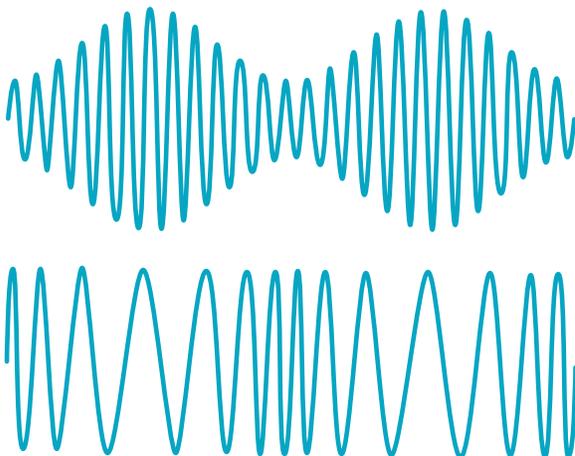
Checking Concepts

Choose the word or phrase that best answers the question.

- If the distance between the crest and trough of a wave is 0.6 m, what is the wave's amplitude?
A) 0.3 m **C)** 0.6 m
B) 1.2 m **D)** 2.4
- What produces waves?
A) sound **C)** transfer of energy
B) heat **D)** vibrations
- Which of the following has wavelengths longer than the wavelengths of visible light?
A) X rays **C)** radio waves
B) gamma rays **D)** ultraviolet waves

Thinking Critically

- 18. Infer** Radio waves broadcast by a radio station strike your radio and your ear. Infer whether the human ear can hear radio waves. What evidence supports your conclusion?
- 19. Solve an Equation** Robotic spacecraft on Mars have sent radio signals back to Earth. The distance from Mars to Earth, at its greatest, is about 401,300,000 km. About how many minutes would it take a signal to reach Earth from that distance?
- 20. Recognize Cause and Effect** When a musician plucks a string on a guitar it produces sound with a certain pitch. If the musician then presses down on the string and plucks it, the sound produced has a shorter wavelength. How does the pitch of the sound change?
- 21. Interpret Scientific Illustrations** One way that radio waves can carry signals to radios is by varying the amplitude of the wave. This is known as amplitude modulation (AM). Another way is by varying the frequency. This is called frequency modulation (FM). Which of the waves below shows AM, and which shows FM? Explain.



- 22. Infer** When light passes through a prism, infer how the amount of bending of a light wave depends on the frequency of the light wave. How does the amount of bending depend on the wavelength of the light wave?
- 23. Describe** how the lenses in your eyes change shape when you first look at your wristwatch to read the time, and then look at a mountain in the distance.

Performance Activities

- 24. Poster** Investigate a musical instrument to find out how it produces sound. Make a poster showing the instrument and describing how it works.
- 25. Model** Make an instrument out of common materials. Present the instrument to the class, and explain how it can produce different pitches.

Applying Math

- 26. Noise Levels** A noisy restaurant has an intensity of about 80 dB, and a lawn mower has an intensity of about 110 dB. How many times louder does the lawn mower noise seem?
- 27. Wavelength of Sound** Sound waves with a frequency of 150 Hz travel at a speed of 340 m/s. What is the wavelength of the sound waves?
- 28. Ultrasound** Physicians sometimes use high-frequency sound waves to diagnose and monitor medical conditions. A typical frequency for the sound waves is about 5,000,000.0 Hz. Sound travels through soft body tissue at about 1500.0 m/s. What is the wavelength of the sound waves?
- 29. Frequency of Radio Waves** Find the frequency of radio waves that have a wavelength of 15 m if they are traveling at a speed of 300,000,000 m/s.

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which of the following terms refers to the bending of waves around objects?
- A. diffraction C. refraction
B. reflection D. transmission

Use the table below to answer questions 2 and 3.

Speed of Sound in Different Materials	
Material	Speed (m/s)
Air (20°C)	343
Glass	5,640
Steel	5,940
Water (25°C)	1,493
Seawater (25°C)	1,533

2. The table above shows the speed of sound through different materials. About how far can sound travel in air in 2.38 s if the air temperature is 20°C?
- A. 144 m C. 684 m
B. 343 m D. 816 m
3. Sound travels 2,146 m through a material in 1.4 seconds. What is the material?
- A. air (20°C) C. water (25°C)
B. glass D. seawater (25°C)
4. Which of the following are not able to travel through empty space?
- A. gamma rays C. sound waves
B. ultraviolet waves D. light waves

Test-Taking Tip

Be Well-Rested Get plenty of sleep—at least eight hours every night—during test week and the week before the test.

5. Which of the following is a true statement?
- A. Waves do not transport the matter through which they travel.
B. Waves can transport matter through solids, liquids, and gases, but not through empty space.
C. Waves can transport matter through liquids and solids, but not through gases or empty space.
D. Sound and water waves can transport matter, but light waves can't.

Use the following table to answer questions 6 and 7.

Decibel Scale	
Sound Source	Loudness (dB)
jet plane taking off	150
running lawn mower	100
average home	50
whisper	15

6. The table above shows typical sound intensity values on a decibel scale. Which of the following would you expect to be the approximate sound intensity of a noisy restaurant?
- A. 20 dB C. 80 dB
B. 40 dB D. 120 dB
7. What sound intensity level would you expect to be painful to most humans?
- A. 30 dB C. 90 dB
B. 60 dB D. 120 dB
8. What is the maximum range of sound frequencies that humans can hear?
- A. 0 to 150 Hz C. 20 to 5000 Hz
B. 0 to 200 Hz D. 20 to 20,000 Hz

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- If the intensity of a sound increases by 20 dB, by what factor is the energy carried by the sound wave increased?
- Why do concert halls often have drapes or other soft material on the walls?

Use the illustration below to answer questions 11 and 12.



- The photograph above shows flashes of lightning strikes during a thunderstorm. Why do you sometimes hear thunder at about the same time you see the flash of lightning, but other times you hear the thunder after the flash?
- You hear thunder 3.0 seconds after you see a lightning flash. Later you hear thunder 2.5 seconds after you see a flash. If the sound travels at 340 m/s, how much closer was the second lightning strike than the first one?
- The frequency of a sound is 37.5 Hz, and the sound travels through air at 343 m/s. What is the wavelength of the sound?
- The speed of all electromagnetic waves through space is 300,000,000 m/s. What is the frequency of a radio wave that has a wavelength of 10 m?

Part 3 Open Ended

Record your answers on a sheet of paper.

- Compare and contrast light waves and sound waves.
- Describe the process that occurs when light waves enter your eye and produce a signal in the optic nerve.
- Name the different types of electromagnetic waves from longest to shortest wavelength. Give an example of each type.
- Describe compressional and transverse waves. Explain the difference between them.
- Explain why sound travels faster through some types of matter than through others. How does temperature affect the speed of sound through a material?

Use the photograph below to answer questions 20 and 21.



- The girl in the photograph above produces sound by clapping cymbals together. Describe how the cymbals produce sound.
- What determines the intensity of the sound that the girl produces with the cymbals? How does this affect whether the sound is loud or soft?
- If you stand near a large tree, you can hear someone talking on the other side of the tree. Explain why you can hear the person, but can't see them.