chapter 9

Introduction to Waves

section 3 The Behavior of Waves

Before You Read

Think about a time when you walked down an empty hallway and heard the echo of your footsteps. Write what you think caused the echo.

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What You'll Learn

- the law of reflection
- how waves change direction
- what are refraction and diffraction
- how waves interfere with each other

Read to Learn

Reflection

Suppose you and a friend are the last students to leave your school building. You shout to your friend at the other end of the hallway. Your voice echoes throughout the hallway. You also notice your reflection in one of the glass windows. These are both examples of wave reflection. Wave reflection causes the echo you hear and the image you see of yourself. Wave reflection happens when a wave strikes an object or surface and bounces off it. All types of waves—including sound, water, and light waves—can be reflected.

How do light waves reflect?

What happens when you see your face in a mirror? First, light waves strike your face and bounce off. Then, the reflected light strikes the mirror and reflects back to your eyes.

What are echoes?

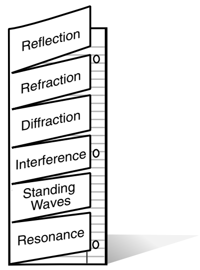
Echoes are reflected sound waves. When you called to your friend in the school building, your voice echoed around the hall. Sound waves formed when you shouted. The waves traveled through the air to your ears and to other objects. The waves reflected off the walls, floor, and ceiling and then came back to your ears. You could hear your voice again, a few seconds after you first heard your voice. This caused the echo. Dolphins and bats use echoes to determine where objects are. Dolphins make clicking noises and listen to the echoes.

Study Coach

Create a Quiz Write questions on index cards as you read this section. After you read, form a group of three students. Take turns asking each other your questions and answering them.

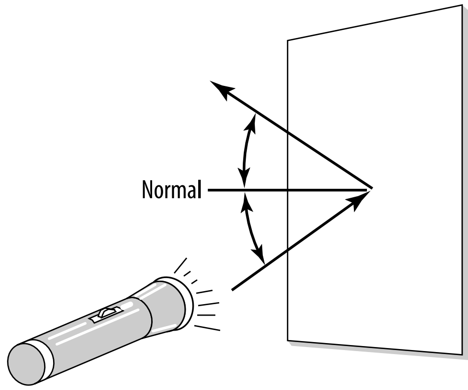
FOLDABLES™

C Build Vocabulary Make the following Foldable. It will help you understand the content of this section by defining the terms used.



What is the law of reflection?

The figure below shows a flashlight shining on a mirror. The light beam that strikes the mirror is called the incident beam. The light beam that bounces off the mirror is called the reflected beam. The line that is at a right angle to the mirror is called the normal. The angle made by the incident beam and the normal is the angle of incidence. The angle made by the reflected beam and the normal is the angle of reflection. The law of reflection says that the angle of incidence is equal to the angle of reflection.



Reflection

Refraction

Picture This

1. **Label** On the figure of the flashlight and the mirror, label the incident beam as *i* and the reflected beam as *r*.

Refraction

Suppose you put a pencil in a glass of water and then look at it from the side of the glass as shown above. The pencil looks like it is broken in two at the water line. But if you pull the pencil out of the water, you see that it is not broken. What makes the pencil appear broken?

What is refraction?

Remember that a wave's speed depends on the medium it is moving through. When a wave moves from one medium to another, such as from water to air, it changes speed. If this wave travels at an angle when it passes from one medium to another, it changes direction, or bends, as it changes speed. **Refraction** is the bending of a wave caused by a change in its speed as it moves from one medium to another. Two things happen to the light waves as they move from the air to the water in the glass. The light waves change speed and direction. They are refracted so the pencil appears to be broken.

Reading Check

2. **Identify** What can change the speed of a wave?

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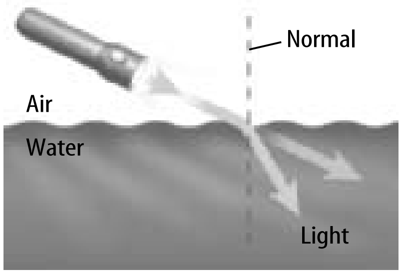
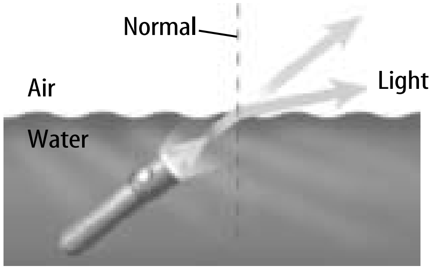
When does light bend?

When a light wave passes into a material in which it slows down, it bends toward the normal. When a light wave passes into a material in which it speeds up, the wave bends away from the normal.

Refractions The figures show what refractions look like. The figure on the left shows light waves moving from air to water. The light waves slow down when they enter the water. This makes them change direction and bend toward the normal. The figure on the right shows light waves moving from water to air. The waves speed up and bend away from the normal.



Air to water



Water to air

Picture This

3. **Highlight** Look at the figure on the right. Use your highlighter to trace the angle that shows the light bending away from the normal.

How does light bend in water?

Have you ever noticed that the feet of someone standing in a swimming pool look closer to the surface than they really are? Your brain wants to think that the light waves travel in a straight line. But refraction causes the light waves from the feet to bend away from the normal as they pass from the water to the air.

This is similar to the pencil in the glass of water. The pencil looks broken at the surface of the water. The light waves coming from the part of the pencil above the water are not bent. The light waves that move from the air to the water in the glass change speed and bend. This makes the part of the pencil that is under water look like it has shifted.

Diffraction

Suppose you are in a classroom and you hear music coming from another room. The sound waves bend around corners and travel from the room down the hall to where you are. Refraction does not cause sound waves to bend. Instead, they bend because of diffraction. **Diffraction** takes place when an object causes a wave to change direction and bend around it.

Light waves can diffract, too. Light waves do not diffract as much as sound waves do. Suppose you walk toward the room where you hear the music. As you walk toward the open door, you can see light coming out of the room. Light waves bend around the edges of the open door. But the amount of light that bends is not enough for you to be able to see around the corner and into the room. Yet, you can hear the music that is being played in the room.

Reading Check

4. **Identify** Circle the term that describes the bending of a wave around an object.
   a. reflection
   b. refraction
   c. diffraction
   d. rarefaction

Picture This

5. Trace Using a pencil, trace along the waves in the figure that have passed through the opening. What happens to the waves after they pass through the opening?

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Think it Over

6. Apply Why is it hard to see around a corner?

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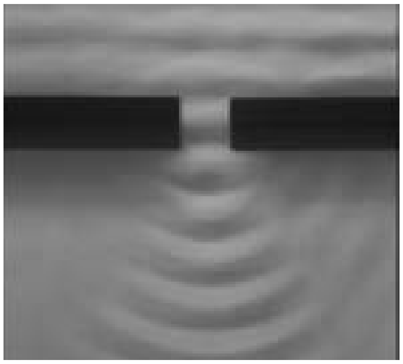
When do water waves diffract?

Ocean waves refract when they strike an island. The waves change direction and bend around the island. Diffraction and refraction both cause waves to bend, but there is a difference. Waves refract when they pass through an object. They diffract when they pass around an object.



Waves also can diffract when they pass through a narrow opening. The figure shows water waves passing through a small opening in a barrier. They diffract and spread out after they pass through the opening. The waves are bending around the corners of the opening.

How much will a wave bend?

To find out how much a wave will bend when it strikes an object, compare the size of the object to the wavelength. When an object is smaller than the wavelength, the waves bend around it. Suppose you shine a large spotlight on a very thin tree. The object is smaller than the wavelength, so the light waves bend around the tree. The shadow is narrower than the tree. A large amount of diffraction takes place. Suppose you shine a small flashlight on a very large tree. The object is larger than the wavelength, so the light waves will not bend around the tree easily. The shadow is wider than the tree. Almost no diffraction takes place.

How do sound waves bend around corners?

Think back to the example of the music coming from another room in your school. You can hear the sounds before you reach the door. The wavelengths of sound waves are about the same size as the door opening. The sound waves diffract around the doorway and spread out into the hallway.

How is this different from the light waves in the room? You aren't able to see into the room because light waves have a much shorter wavelength than sound waves. This is why the light waves are not diffracted by the doorway as much as the sound waves are.

How do radio waves diffract?

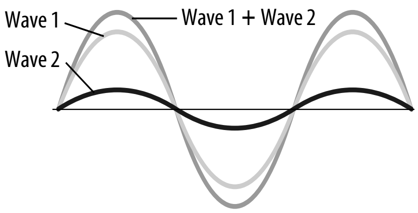
AM radio waves have longer wavelengths than FM radio waves. So, AM radio waves can diffract around big objects much more than FM radio waves. You can get more AM than FM radio stations when you are near tall buildings and hills.

Interference

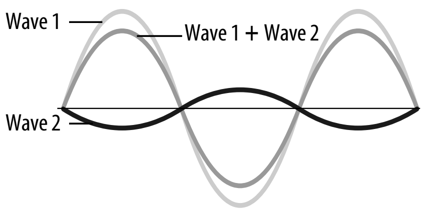
Suppose you throw two pebbles into a still pond. Each pebble causes ripples to form around it. The waves of ripples travel toward each other. When the two waves meet, they pass right through each other and continue moving. **Interference** is the point where two waves meet each other and overlap to form a new wave. The new wave lasts only as long as the two waves continue to overlap. There are two kinds of interference, constructive and destructive.

What is constructive interference?

The left-hand figure below shows constructive interference. In constructive interference, the waves meet at the same point and add together. This happens when the crests of transverse waves overlap each other. The troughs of the waves also overlap. The amplitudes of the two waves add together to make a larger wave. So, the new wave has a higher crest and a lower trough. The amplitude of the new wave is the sum of the amplitudes of the other two waves. Constructive interference also happens when two compressional waves overlap. When the compressions of one wave overlap the compressions of another, the compressions add to make a combined wave with a larger amplitude. If they are sound waves, the new wave is louder.



Constructive Interference



Destructive Interference

What is destructive interference?

In destructive interference, the overlapping waves subtract from each other. This happens when the crest of one transverse wave overlaps with the trough of another transverse wave. The amplitudes of the two waves combine to make a new wave with a smaller amplitude. The figure above on the right shows the new wave that forms during destructive interference.

The same is true for longitudinal waves. When the compression of one wave overlaps the rarefaction of the other wave, destructive interference occurs. The compressions and rarefactions combine to form a smaller wave. In sound waves, destructive interference causes a decrease in loudness.

Think it Over

7. **Describe** a time when you heard or used the word *interference* or *interfere*.

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Picture This

8. **Use Models** In both figures, use a highlighter to trace over the new wave that forms during either constructive or destructive interference.

Standing Waves

Suppose you and a friend are holding the ends of the same rope. You both shake the rope and make waves the same size that travel toward each other. Interference happens when the waves from one end overlap waves from the other end. A new wave forms when a crest of one of your waves meets a crest of one of your friend's waves. The new wave has a larger amplitude.

When a crest of one wave meets a trough of another wave, the waves cancel each other out. Then there is no movement. A **standing wave** is a wave pattern that forms when two equal-sized waves travel in opposite directions and continuously interfere with each other. The interference of these two waves makes the rope vibrate and creates a pattern of crests and troughs. This makes it look like the rope is standing still. Nodes are the places where the two waves cancel each other. The nodes always stay in the same place on the rope. The wave pattern vibrates between the nodes.

Reading Check

9. Describe What happens when a crest of one wave meets a trough of another wave of the same amplitude?

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What are some standing waves?

When you use a bow to play a violin, the string vibrates and creates standing waves. The standing waves in the string make a rich, musical tone. Other instruments also use standing waves to create music. A flute creates standing waves in a column of air. The material in a drumhead vibrates to make standing waves.

Resonance

Bells of different sizes and shapes make different sounds. When you strike a bell, it vibrates at its own natural frequencies. All objects have their own natural frequencies of vibration. The frequencies depend on the size and shape of the object. Frequency also depends on the kind of material that the object is made of.

There is another way to make an object vibrate at its natural frequencies. Suppose you have a tuning fork with a single natural frequency. Imagine that a sound wave of the same frequency strikes the tuning fork. Because the sound wave has the same frequency, the tuning fork will vibrate. **Resonance** is when an object vibrates by absorbing energy from another object that is vibrating at the same natural frequencies.

Resonance can cause an object to absorb a large amount of energy. An object vibrates more strongly as it keeps absorbing more energy at its natural frequencies. If enough energy is absorbed, the object can vibrate too much and break apart.

Think it Over

10. Summarize How can resonance cause an object to break?

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After You Read

Mini Glossary

diffraction: the bending of a wave around a barrier

interference: the point where two waves meet each other and overlap to form a new wave

node: location where interfering standing waves cancel

refraction: the bending of a wave caused by a change in its speed as it moves from one medium to another

resonance: the vibration of an object by absorbing energy from another object that is vibrating at its natural frequencies

standing wave: a wave pattern that forms when two equal-sized waves travel in opposite directions and interfere with each other

1. Review the key terms and their definitions in the Mini Glossary. How are refraction and diffraction the same? How are they different?

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2. List the main ideas you learned about the behavior of waves. For help, use the main headings in the section.

The Behavior of Waves

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

3. Study Coach Look at the questions you wrote on index cards during this section. How did writing these questions help you learn?

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End of Section