chapter 1

Waves

section 3 Wave Behavior

What You'll Learn

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

Before You Read

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

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**.

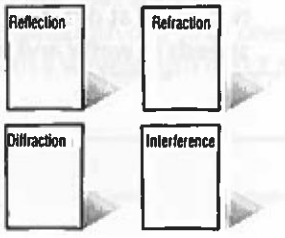
Mark the Text

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

FOLDABLES™

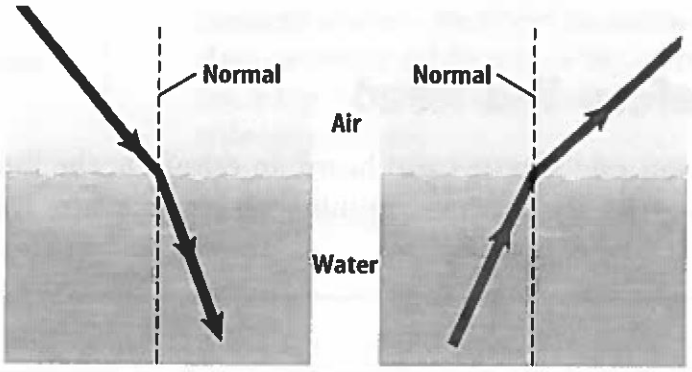
Organize Information

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.



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

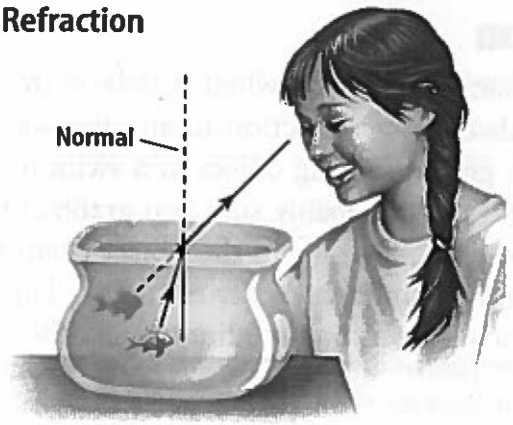
1. **Display** In the water of the first figure, draw an arrow from the light ray to the normal that shows how the light ray bends toward the normal.

   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.

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?

_____

_____

_____

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?

_____

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?

_____

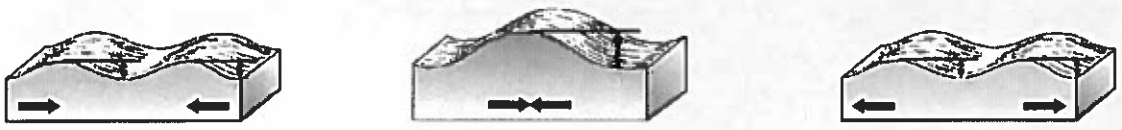
_____

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

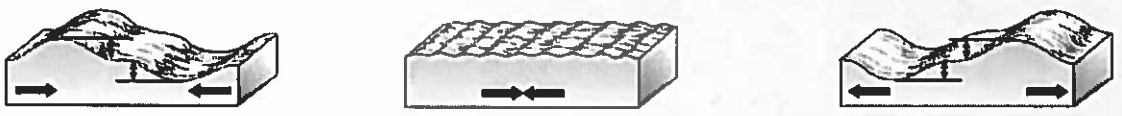


Destructive Interference In destructive interference, the crest of one wave overlaps the trough of another. The amplitudes of the waves combine to make a wave with a smaller amplitude. If the waves have equal amplitudes, they will cancel each other out while the waves overlap. Then the original waves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

Picture This

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

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. ☑

Reading Check

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

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.

Think it Over

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

After You Read

Mini Glossary

diffraction: the bending of waves around a barrier

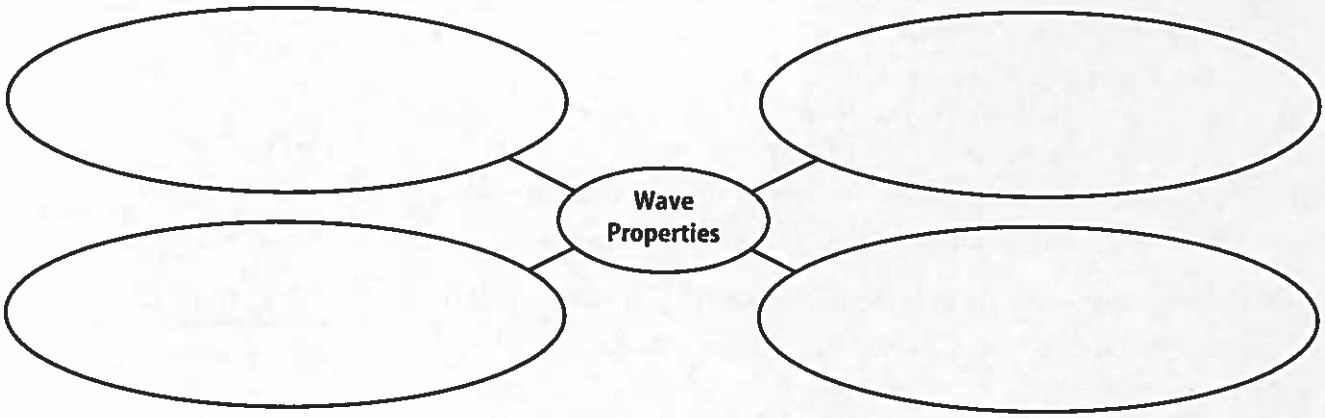
interference: the ability of two waves to combine and make a new wave when they overlap

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.

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.

End of Section

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