KEY IDEAS
As you read this section, keep these questions in mind:
• How do waves behave when they interact with objects?
• What happens when two waves meet?
• How do standing waves form?

How Do Waves Interact with Objects?
Think about a pebble dropped into a pond. The waves that form when the pebble hits the water travel out in circles from the center. What happens when the waves reach the shore, or hit an object in the middle of the pond?
Waves behave in different ways when they interact with different objects. When a wave meets a surface or boundary, the wave can bounce back. When a wave passes the edge of an object or passes through an opening, the wave bends. A wave can also bend when it passes from one medium into another.

REFLECTION
The image below shows an example of water waves hitting a surface, such as a dock or pier. When the waves hit such a surface, they reflect. During reflection, a wave bounces back when it meets a surface or boundary.

All kinds of waves can reflect when they hit a surface. For example, visible light reflects off of objects it strikes. The reflected light travels to your eyes, allowing you to see the objects. Echoes are another example of reflection. If you shout into a large, empty space, the sound waves reflect off the walls, ceiling, and floor. They travel back to your ears, producing an echo.

READING TOOLBOX
Compare After you read this section, make a chart comparing reflection, refraction, diffraction, and interference.

READING CHECK
1. Describe What happens when a wave passes the edge of an object?

LOOKING CLOSER
2. Define What happens to a wave during reflection?

Reflection occurs when waves bounce off a surface.
If you stand outside the doorway of a classroom, you may be able to hear voices inside the room. Sound waves cannot travel in a straight line through the wall to your ears. How can you hear the voices?

When waves pass the edge of an object, they bend and spread out on the other side. The same effect occurs if waves pass through an opening, such as an open door or window. The waves bend around the corner or opening.

Think back to the waves in the pond. What would happen if the waves passed through a gap between two objects? You might see something like the figure below. The waves bend around the two edges and spread out as they pass through the gap. Scientists call this effect `diffraction`.

The amount of diffraction of a wave depends on its wavelength and the size of the barrier or opening.

**Diffraction**

Diffraction occurs when waves pass through an opening or around a corner. The waves bend as they pass the corners.

Sound waves behave the same way when they pass through a door. As the waves pass through the door, they bend and travel into the space near the door. Because they spread out into the space beyond the door, a person near the doorway can hear sounds from inside the room.

**REFRACTION**

Imagine a spoon in a glass of water, such as the one shown at the top of the next page. The spoon looks like it is broken into two pieces where it enters the water. This occurs because light waves bend as they enter and leave the water. Scientists call this effect `refraction`. 
When waves move from one medium to another, they refract, or bend. The refraction of light waves makes this spoon look broken.

Light waves that reflect off the top of the spoon pass through only air before reaching your eyes. Waves that reflect off the bottom of the spoon travel through water, glass, and air before reaching your eyes. The waves bend slightly each time they enter a new medium, because their speed changes. Because of refraction, light reflected from the top and from the bottom of the spoon reach your eyes at different angles. That’s why the spoon seems to be broken.

**What Happens When Waves Combine?**

Imagine two people trying to walk through a narrow doorway at the same time. They will run into each other. Material objects, such as human bodies, cannot take up exactly the same space at the same time.

Waves are different. When two or more waves occupy the same space, they combine to form a single new wave. The process is called **interference**. An example of interference is shown in the photo below.

A new wave produced by interference differs from the original waves. When the waves have passed through each other, they return to their original shapes.

**LOOKING CLOSER**

5. **Infer** Would the spoon look broken if it was completely under the water?

**Critical Thinking**

6. **Infer** Light bends more when it moves from air into oil than from air into water. Will an object placed in a container of oil look more bent or less bent than it would in a container of water? (Hint: If there is no refraction, the object won’t look bent.)

**READING CHECK**

7. **Define** What is interference?
CONSTRUCTIVE AND DESTRUCTIVE INTERFERENCE

There are two main types of wave interference: constructive interference and destructive interference. **Constructive interference** happens when the amplitude of the combined waves is larger than the amplitudes of the single waves. This can occur when the crests of two transverse waves overlap, as in the figure below.

Looking Closer

8. **Calculate** The amplitudes of the two waves are 4 cm and 3 cm. What is the amplitude of the combined wave?

In constructive interference, the amplitude of the combined wave is the sum of the amplitudes of the two overlapping waves.

Destructive interference happens when the amplitude of the combined waves is smaller than the amplitudes of the single waves. This can occur when the crest of one transverse wave overlaps the trough of another. If both waves have the same amplitude, they may cancel out each other completely, as shown below.

Looking Closer

9. **Infer** The amplitude of the combined wave is zero. What must the relative amplitudes of the two waves be?

In destructive interference, the amplitude of the combined wave is the difference of the amplitudes of the two overlapping waves.

INTERFERENCE IN LIGHT AND SOUND WAVES

If you look at a soap bubble, you may see swirling colors on its surface. These colors are produced by interference of light waves reflecting off of different parts of the bubble.

Interference can also affect sound waves. For example, the notes from two different tuning forks can interfere with each other. This interference can produce a pattern of loud and soft sounds called beats. Piano tuners often compare the sound of a piano string with that from a tuning fork. When there are no beats, the piano string and the tuning fork are vibrating at the same frequency. This means the piano string is in tune.
What Are Standing Waves?

Suppose you send a wave through a rope that has one end tied to a wall. The wave reflects from the wall and travels back along the rope. As you send more waves down the rope, they will interfere with the reflected waves. When a wave interferes with its reflection, it can form a standing wave. Two examples of standing waves are shown in the figures below.

Standing waves can form when a wave interferes with its reflection.

A standing wave causes the medium to vibrate as if it is staying still. It appears that the wave is a single, stationary one. However, a standing wave really consists of two waves traveling in opposite directions.

NODES AND ANTINODES

Standing waves form loops, as shown in the images above. Certain points that have no vibration, called nodes, separate the loops. Nodes lie at the points where the crests of the original waves meet the troughs of the reflected waves. In other words, nodes are points of complete destructive interference. The top wave above has a node at each end. The bottom wave has three nodes: two at the end and one in the middle.

Midway between two nodes, the crests of the original and reflected waves combine in complete constructive interference. These points are called antinodes. The top wave above has a single antinode in the middle. The bottom wave has two antinodes, one on the left and one on the right.

READING CHECK

10. Define What is a standing wave?

11. Describe What does a standing wave look like?

12. Compare How is a node different from an antinode?
Section 3 Review

SECTION VOCABULARY

constructive interference a superposition of two or more waves that produces an intensity equal to the sum of the intensities of the individual waves

destructive interference a superposition of two or more waves that produces an intensity equal to the difference of the intensities of the individual waves

diffraction a change in the direction of a wave when the wave finds an obstacle or an edge, such as an opening

interference the combination of two or more waves that results in a single wave

reflection the bouncing back of a ray of light, sound, or heat when the ray hits a surface that it does not go through

refraction the bending of a wave front as the wave front passes between two substances in which the speed of the wave differs

standing wave a pattern of vibration that simulates a wave that is standing still

1. Compare Give one difference and one similarity between constructive interference and destructive interference.

2. Identify What allows you to hear sounds in a room when you are standing outside the door? Explain how this effect works.

3. Compare How is refraction different from diffraction?

4. Infer The crest of wave A has an amplitude of 5 cm. The trough of wave B has an amplitude of 2 cm. If the crest of wave A combines with the trough of wave B, what will be the amplitude of the resulting wave? Will the waves form a crest or a trough when they combine?

5. Draw Conclusions A student ties a rope to a doorknob. The student moves the rope to create a standing wave with two nodes and one antinode. In the space below, draw what the standing wave looks like.