

Wave Interactions and Interference

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CHAPTER 1

Wave Interactions and Interference

Lesson Objectives

- Describe wave reflection, refraction, and diffraction.
- Explain how wave interference affects the amplitude of waves.

Lesson Vocabulary

- diffraction
- reflection
- refraction
- standing wave
- wave interference

Introduction

Did you ever hear an echo of your own voice? An echo occurs when sound waves bounce back from a hard object. The man in **Figure 1.1** is trying to create an echo by shouting toward a rock wall. When the sound waves strike the rock wall, they can't pass through. Instead, they bounce back toward the man, and he hears an echo of his voice. An echo is just one example of how waves interact with matter.

Wave Interactions

Waves interact with matter in several ways. The interactions occur when waves pass from one medium to another. Besides bouncing back like an echo, waves may bend or spread out when they strike a new medium. These three ways that waves may interact with matter are called reflection, refraction, and diffraction. Each type of interaction is described in detail below. For animations of the three types of wave interactions, go to this URL: <http://www.acoustics.salford.ac.uk/schools/teacher/lesson3/flash/whiteboardcomplete.swf> .

Reflection

An echo is an example of wave reflection. Reflection occurs when waves bounce back from a barrier they cannot pass through. **Reflection** can happen with any type of waves, not just sound waves. For example, **Figure 1.2** shows the reflection of ocean waves off a rocky coast. Light waves can also be reflected. In fact, that's how we see most objects. Light from a light source, such as the sun or a light bulb, shines on the object and some of the light is reflected. When the reflected light enters our eyes, we can see the object.



FIGURE 1.1

This man is sending sound waves toward a rock wall so he can hear an echo.



FIGURE 1.2

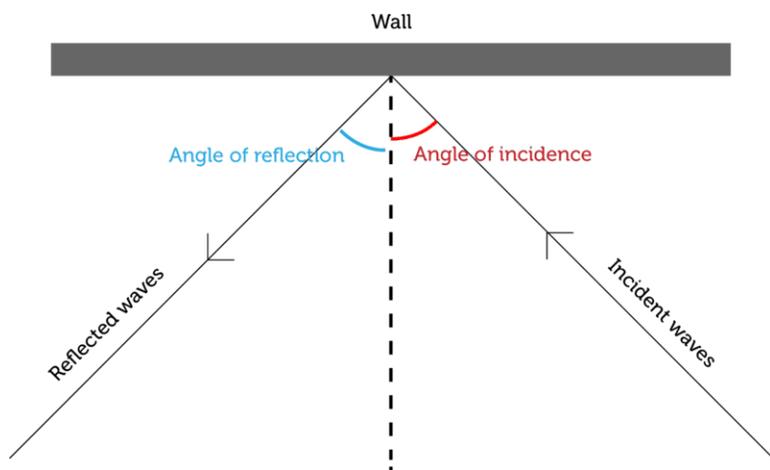
Ocean waves are reflected by rocks on shore.

Reflected waves have the same speed and frequency as the original waves before they were reflected. However, the direction of the reflected waves is different. When waves strike an obstacle head on, the reflected waves bounce straight back in the direction they came from. When waves strike an obstacle at any other angle, they bounce back at the same angle but in a different direction. This is illustrated in **Figure 1.3**.

Refraction

Refraction is another way that waves interact with matter. **Refraction** occurs when waves bend as they enter a new medium at an angle. You can see an example of refraction in **Figure 1.4**. Light bends when it passes from air to water. The bending of the light causes the pencil to appear broken.

Why do waves bend as they enter a new medium? Waves usually travel at different speeds in different media. For example, light travels more slowly in water than air. This causes it to refract when it passes from air to water.

**FIGURE 1.3**

Waves strike a wall at an angle, called the angle of incidence. The waves are reflected at the same angle, called the angle of reflection, but in a different direction. Both angles are measured relative to a line that is perpendicular to the wall.

**FIGURE 1.4**

This pencil looks broken where it enters the water because of refraction of light waves.

Diffraction

Did you ever notice that when you're walking down a street, you can hear sounds around the corners of buildings? **Figure 1.5** shows why this happens. As you can see from the figure, sound waves spread out and travel around obstacles. This is called **diffraction**. It also occurs when waves pass through an opening in an obstacle. All waves may be diffracted, but it is more pronounced in some types of waves than others. For example, sound waves bend around corners much more than light does. That's why you can hear but not see around corners.

For a given type of waves, such as sound waves, how much the waves diffract depends on two factors: the size of the obstacle or opening in the obstacle and the wavelength. This is illustrated in **Figure 1.6**.

- Diffraction is minor if the length of the obstacle or opening is greater than the wavelength.
- Diffraction is major if the length of the obstacle or opening is less than the wavelength.

Diffraction of Sound Waves

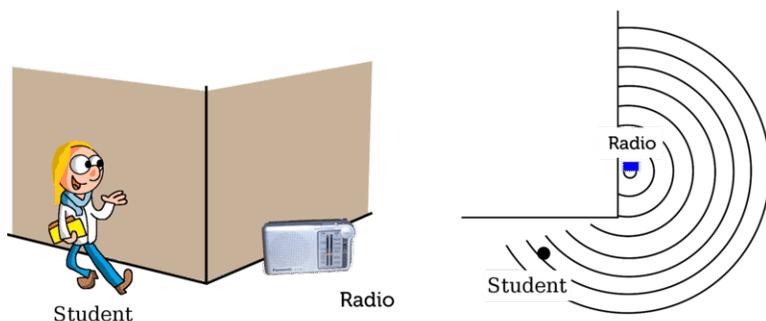


FIGURE 1.5

The person can hear the radio around the corner of the building because of the diffraction of sound waves.

How Diffraction Occurs

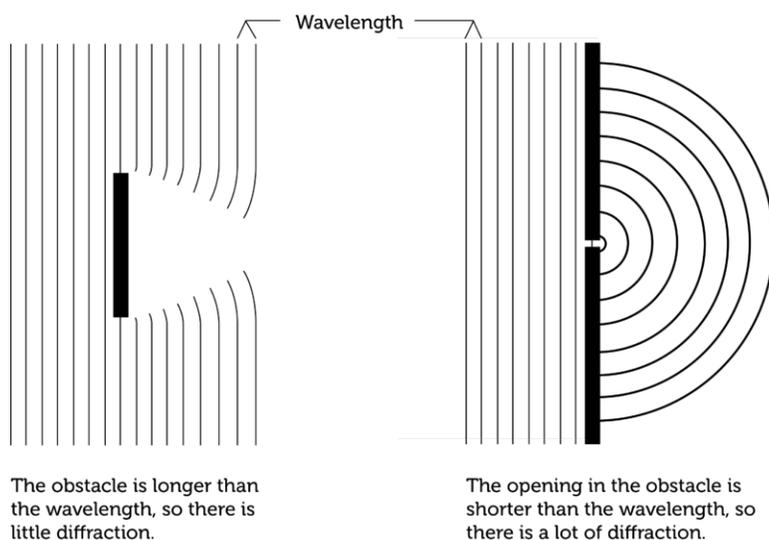


FIGURE 1.6

An obstacle or opening that is shorter than the wavelength causes greater diffraction of waves.

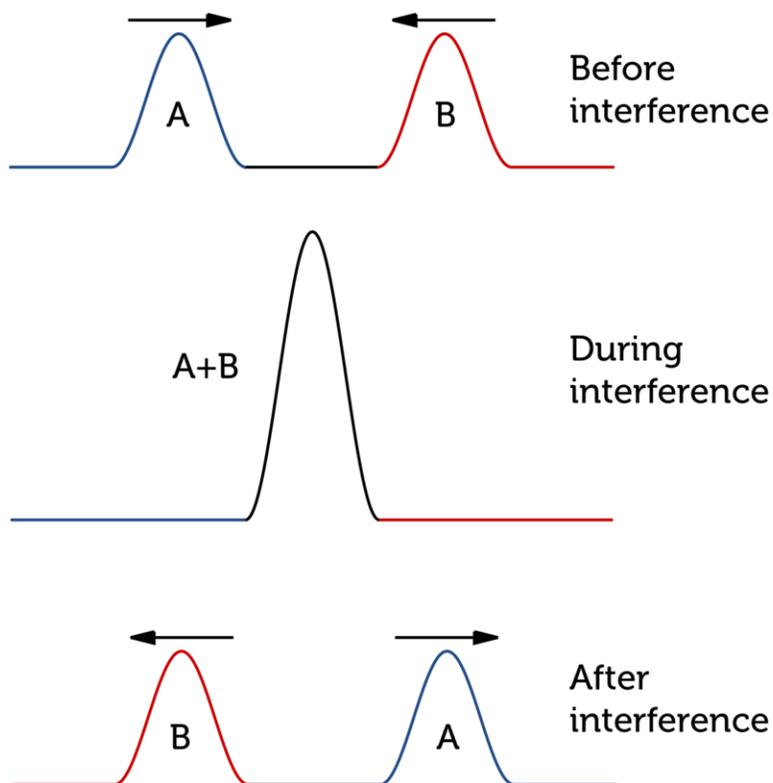
Wave Interference

Waves interact not only with matter in the ways described above. Waves also interact with other waves. This is called **wave interference**. Wave interference may occur when two waves that are traveling in opposite directions meet. The two waves pass through each other, and this affects their amplitude. How amplitude is affected depends on the type of interference. Interference can be constructive or destructive.

Constructive Interference

Constructive interference occurs when the crests of one wave overlap the crests of the other wave. This is illustrated in **Figure 1.7**. As the waves pass through each other, the crests combine to produce a wave with greater amplitude. You can see an animation of constructive interference at this URL: http://phys23p.sl.psu.edu/phys_anim/waves/embedderQ1.20100.html .

Constructive Interference

**FIGURE 1.7**

Constructive interference increases wave amplitude.

Destructive Interference

Destructive interference occurs when the crests of one wave overlap the troughs of another wave. This is illustrated in **Figure 1.8**. As the waves pass through each other, the crests and troughs cancel each other out to produce a wave with less amplitude. You can see an animation of destructive interference at this URL: http://phys23p.sl.psu.edu/phys_anim/waves/embederQ1.20200.html .

Standing Waves

When a wave is reflected straight back from an obstacle, the reflected wave interferes with the original wave and creates a **standing wave**. This is a wave that appears to be standing still. A standing wave occurs because of a combination of constructive and destructive interference between a wave and its reflected wave. You can see animations of standing waves at the URLs below.

- <http://skullsinthestars.com/2008/05/04/classic-science-paper-otto-wieners-experiment-1890/>
- <http://www.physicsclassroom.com/mmedia/waves/swf.cfm>

It's easy to generate a standing wave in a rope by tying one end to a fixed object and moving the other end up and down. When waves reach the fixed object, they are reflected back. The original wave and the reflected wave interfere to produce a standing wave. Try it yourself and see if the wave appears to stand still.

Destructive Interference

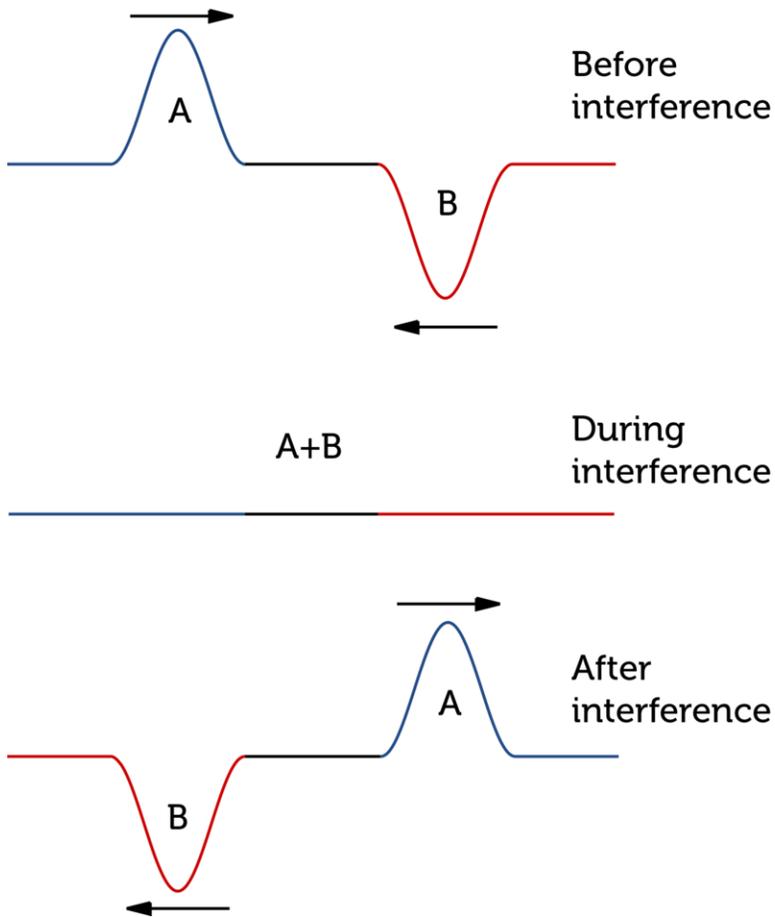


FIGURE 1.8

Destructive interference decreases wave amplitude.

Lesson Summary

- Reflection occurs when waves bounce back from a barrier they cannot pass through. Refraction occurs when waves bend as they enter a new medium at an angle. Diffraction occurs when waves spread out around an obstacle or after passing through an opening in an obstacle.
- Wave interference occurs when waves interact with other waves. Constructive interference increases wave amplitude. Destructive interference decreases wave amplitude.

Lesson Review Questions

Recall

1. What is reflection? Give an example.
2. Define constructive interference.
3. State how destructive interference affects wave amplitude.

4. What is a standing wave?

Apply Concepts

5. Create a sketch of sound waves to show why you can hear a sound on the other side of brick wall.

Think Critically

6. Explain why the pencil in **Figure 1.4** appears broken.
7. A sound wave meets an obstacle it cannot pass through. Relate the amount of diffraction of the sound wave to the length of the obstacle and the wavelength.

Points to Consider

You were introduced to sound waves in this chapter, and you will learn more about them in the chapter "Sound."

- How do you think we hear sound waves?
- What properties of sound waves might determine how loud a sound is?

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