Diffraction of Water Waves 9.2

Periodic straight wave fronts in a ripple tank travel in a straight line as long as the depth of the water is constant and the water is free of obstacles. If the waves pass by a sharp edge of an obstacle or through a small opening or aperture in an obstacle, the waves spread out, as illustrated in **Figure 1**(**a**). This bending is called **diffraction**. One of the easiest ways to observe the properties of the diffraction of waves is with a ripple tank. Investigation 9.2.1, in the Lab Activities section at the end of this chapter, provides an opportunity for you to observe and interpret the phenomenon of diffraction.

How much the waves are diffracted at an opening in a barrier depends on both their wavelength and the size of the opening. **Figures 1**(**b**) and (**c**) show that shorter wavelengths are diffracted slightly, while longer wavelengths are diffracted to a greater extent by the same edge or opening.

diffraction the bending effect on a wave's direction as it passes through an opening or by an obstacle

INVESTIGATION 9.2.1

Diffraction of Water Waves (p. 482)

What factors determine how much a wave will diffract? How do these factors relate to one another?

(a) (b) (c)

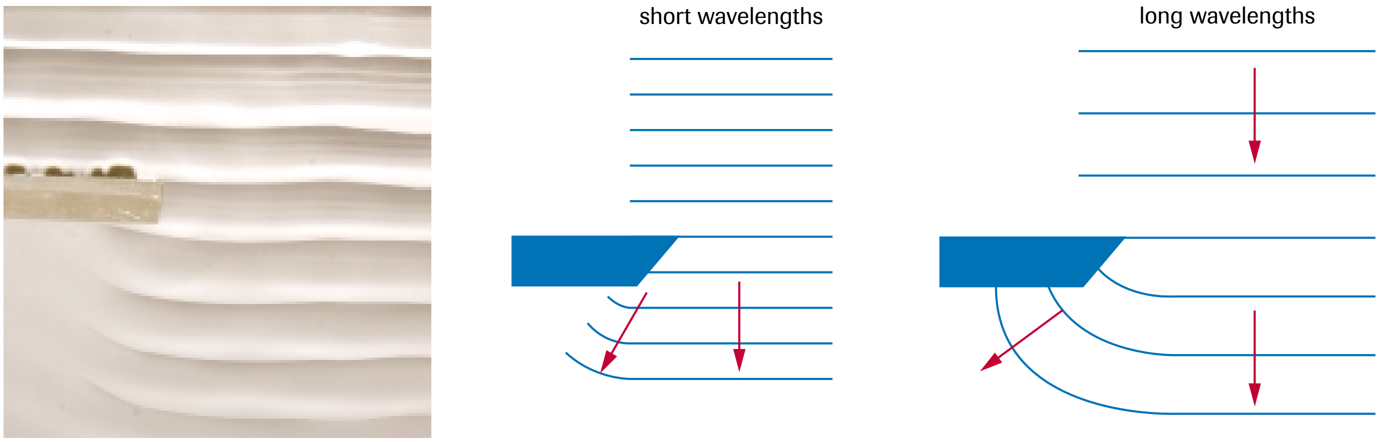

Figure 1
When waves travel by an edge, longer wavelengths are diffracted more than shorter wavelengths.

You can predict how diffraction will vary if you keep the width of the aperture constant and try waves of different wavelengths. In each of the situations in **Figure 2**, the width *w* of the aperture is the same. In **Figure 2**(**a**), the wavelength λ is approximately a third of *w*. Only part of the straight wave fronts pass through, to be converted to small sectors of a series of circular wave fronts. In (**b**), λ is approximately half of *w* and there is considerably more diffraction. There are still shadow areas to the left and right, where none of the waves are diffracted. In (**c**), λ is approximately three-quarters of *w*. Here, the small sections of the straight wave that get through the opening are almost entirely converted

(a) (b) (c)

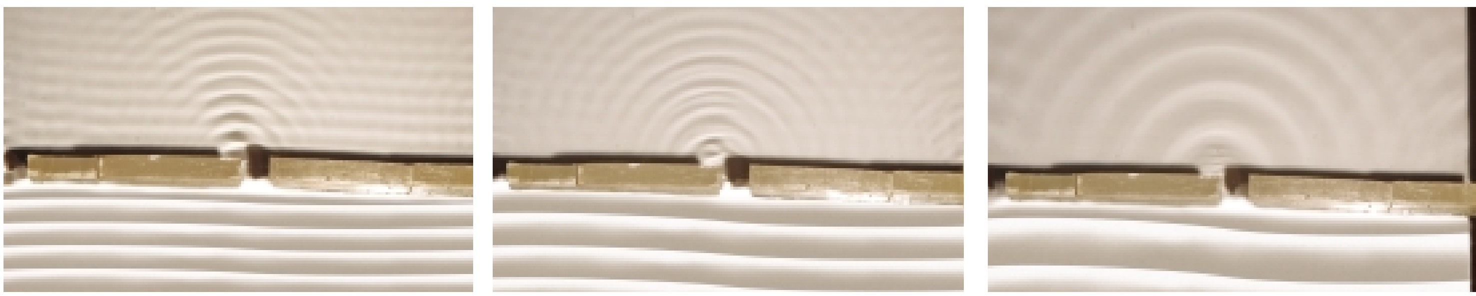

Figure 2
As the wavelength increases, the amount of diffraction increases.

into circular wave fronts. The wave has bent around the side of the opening, filling almost the entire region beyond the barrier.

When we keep λ fixed and change w, we find that the amount of diffraction increases as the size of the aperture decreases. In both instances, if waves are to be strongly diffracted they must pass through an opening of width comparable to their wavelength or smaller $\left(w \leq \lambda;\text{ equivalently } \frac{\lambda}{w} \geq 1\right)$. This means that if the wavelength is very small, a very narrow aperture is required to produce significant diffraction (**Figure 3**).

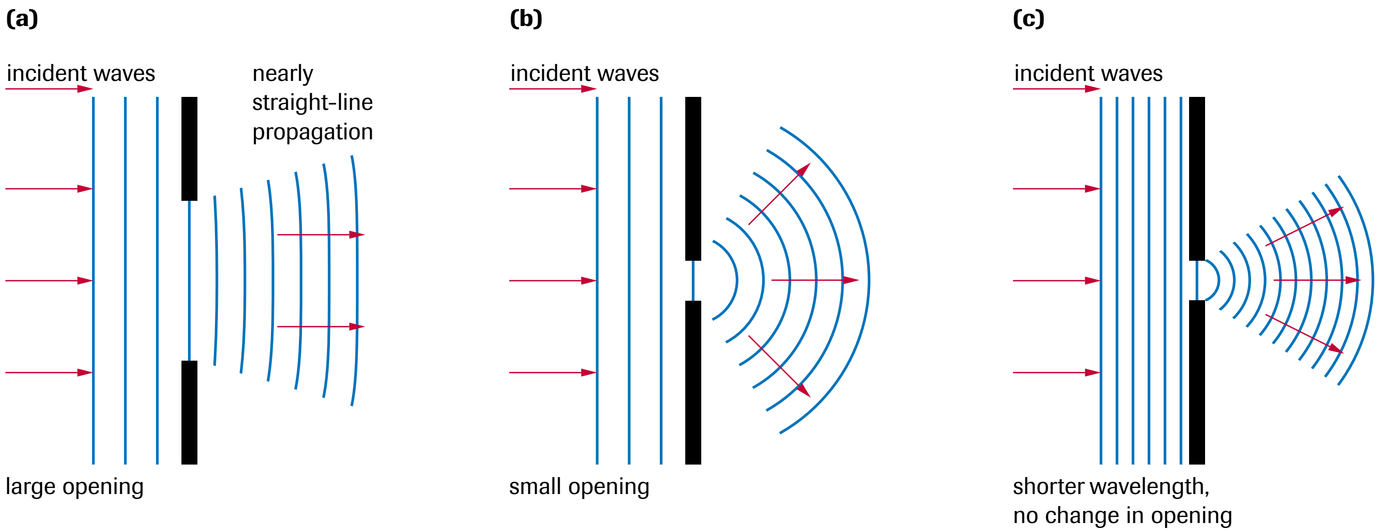

Figure 3
In **(a)** and **(b)**, similar wavelengths are diffracted more through a smaller opening; in **(b)** and **(c)**, the openings are the same size but the wavelengths are shorter in **(c)**, and there is less diffraction.

Perhaps the most obvious example of the diffraction of waves occurs with sound. The sounds of a classroom can be heard through an open door, even though the students are out of sight and behind a wall. Sound waves are diffracted around the corner of the doorway primarily because they have long wavelengths, relative to the width of the opening. If a sound system is operating in the room, its low frequencies (the long wavelengths) are diffracted around the corner more than are its higher frequencies (the shorter wavelengths).

SUMMARY Diffraction of Water Waves

- Waves diffract when they pass by an obstacle or through a small opening.
- Waves of longer wavelength experience more diffraction than waves with a smaller wavelength.
- For a given opening or aperature, the amount of diffraction depends on the ratio $\frac{\lambda}{w}$. For observable diffraction, $\frac{\lambda}{w} \geq 1$.

Section 9.2 Questions

Understanding Concepts

1. State the condition required to maximize the diffraction of waves through an aperature.
2. If waves with a wavelength of 2.0 m pass through an opening of 4.0 m in a breakwater barrier, will diffraction be noticeable?
3. Electromagnetic radiation with a wavelength of 6.3×10^{-4} m passes through a slit. Find the maximum slit width that will produce noticeable diffraction.
4. Will the electromagnetic radiation of question 3 be diffracted by slits wider than the width you calculated? Explain your answer.