**Chapter 43 Reflection and Refraction at Plane Surfaces**

**43-2 REFLECTION AND REFRACTION**

When you look at a pane of window glass, you of course notice that light reaches you from the other side of the glass, and a friend standing on the other side of the glass is able to see you. If you look carefully, however, you may also see your reflection in the glass. If you were to shine a flashlight on the glass, your friend would see the beam of light, but you might also see some of the light reflected back toward you.

In general, these two effects can occur whenever a beam of light travels from one medium (the air, for instance) to another (the glass). Part of the beam may be reflected back into the first medium, and part may be transmitted into the second medium. Figure 3 illustrates these two effects. Note that the beam of light may be bent or refracted as it enters the second medium.*

Geometrical optics includes the study of reflection and refraction. In this section we summarize the laws of reflection and refraction; later in this chapter we derive these laws and give examples of their applications when the boundary between the two media is a plane. Cases in which the boundary is curved, such as in spherical mirrors or lenses, are discussed in the next chapter.

In Fig. 3, the beams are represented by rays. The rays, which are drawn as straight lines perpendicular to the (plane) wavefronts, indicate the direction of motion of the wavefronts. Note the three rays shown in Fig. 3: the original or incident ray, the reflected ray, and the refracted ray, which changes direction as it enters the second medium.

At the point where the incident ray strikes the surface, we draw a line normal (perpendicular) to the surface, and we define three angles measured with respect to the normal: the angle of incidence \( \theta_1 \), the angle of reflection \( \theta'_1 \), and the angle of refraction \( \theta_2 \). (The subscripts on the angles indicate the medium through which the ray travels. In our case, the ray is incident from medium 1, the air, and enters medium 2, the glass.) The plane formed by the incident ray and the normal is called the plane of incidence; it is the plane of the page in Fig. 3.

From experiment, we deduce the following laws governing reflection and refraction:

**The Law of Reflection**  The reflected ray lies in the plane of incidence, and

\[
\theta'_1 = \theta_1. \tag{1}
\]

**The Law of Refraction**  The refracted ray lies in the plane of incidence, and

\[
n_1 \sin \theta_1 = n_2 \sin \theta_2. \tag{2}
\]

*Reflected* comes from the Latin for "broken"; the same root occurs in the word "fracture." If you dip a slanted pencil partly way into a bowl of water, the pencil appears to be "broken."

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*Figure 1* An attempt to isolate a ray by reducing the slit width fails because of diffraction, which becomes more pronounced for a fixed wavelength \( \lambda \) as the slit width \( a \) is reduced.

*Figure 2* Diffraction of water waves at a slit in a ripple tank. Note that the slit width is about the same size as the wavelength. Compare with Fig. 1c.