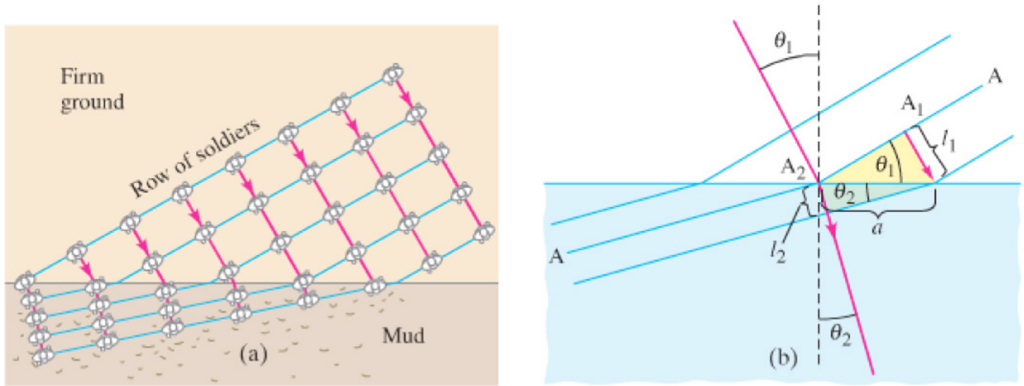

FIGURE 11–43 (a) Soldier analogy to derive (b) law of refraction for waves.

going in the opposite direction, the geometry would not change; only θ_1 and θ_2 would change roles: θ_1 would be the angle of refraction and θ_2 the angle of incidence. Clearly then, if the wave travels into a medium where it can move faster, it will bend the opposite way, $\theta_r > \theta_i$. We see from Eq. 11–20 that if the velocity increases, the angle increases, and vice versa.

PHYSICS APPLIED
Earthquake wave refraction

Earthquake waves refract within the Earth as they travel through rock layers of different densities (and therefore the velocity is different) just as water waves do. Light waves refract as well, and when we discuss light, we shall find Eq. 11–20 very useful.

EXAMPLE 11–15 **Refraction of an earthquake wave.** An earthquake P wave passes across a boundary in rock where its velocity increases from 6.5 km/s to 8.0 km/s. If it strikes this boundary at 30°, what is the angle of refraction?

APPROACH We apply the law of refraction, Eq. 11–20.

SOLUTION Since $\sin 30^\circ = 0.50$, Eq. 11–20 yields

$$\sin\theta_2 = \frac{(8.0\,\mathrm{m/s})}{(6.5\,\mathrm{m/s})}(0.50) = 0.62.$$

So $\theta_2 = \sin^{-1}(0.62) = 38^\circ$.

NOTE Be careful with angles of incidence and refraction. As we discussed in Section 11–11 (Fig. 11–35), these angles are between the wave front and the boundary line, or—equivalently—between the ray (direction of wave motion) and the line perpendicular to the boundary. Inspect Fig. 11–43b carefully.

* 11–15 Diffraction

Waves spread as they travel. When they encounter an obstacle, they bend around it somewhat and pass into the region behind as shown in Fig. 11–44 for water waves. This phenomenon is called **diffraction**.

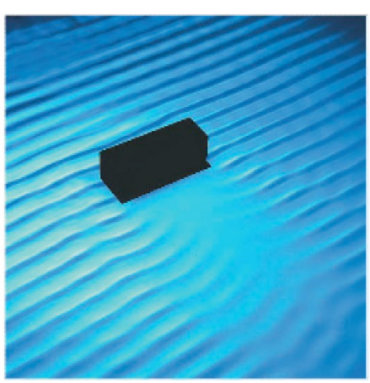

FIGURE 11–44 Wave diffraction. The waves are coming from the upper left. Note how the waves, as they pass the obstacle, bend around it, into the "shadow region" behind it.