transported, $P = E/t$, is

$$P = \frac{E}{t} = 2\pi^2 \rho S v f^2 A^2. \qquad \textbf{(11–17b)}$$

Finally, the **intensity** I of a wave is the power transported across unit area perpendicular to the direction of energy flow:

$$I = \frac{P}{S} = 2\pi^2 v \rho f^2 A^2. \qquad \textbf{(11–18)}$$

This relation shows explicitly that the intensity of a wave is proportional both to the square of the wave amplitude A at any point and to the square of the frequency f.

11–11 Reflection and Transmission of Waves

When a wave strikes an obstacle, or comes to the end of the medium it is traveling in, at least a part of the wave is reflected. You have probably seen water waves reflect off a rock or the side of a swimming pool. And you may have heard a shout reflected from a distant cliff—which we call an "echo."

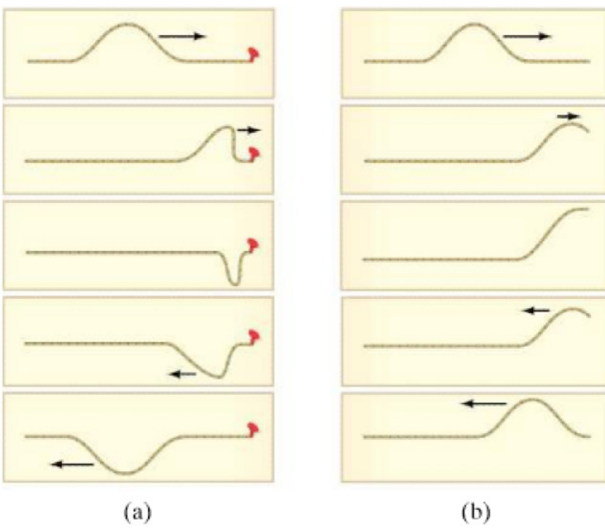

FIGURE 11–32 Reflection of a wave pulse on a rope lying on a table top. (a) The end of the rope is fixed to a peg. (b) The end of the rope is free to move.

A wave pulse traveling down a rope is reflected as shown in Fig. 11–32. The reflected pulse returns inverted as in Fig. 11–32a if the end of the rope is fixed; it returns right side up if the end is free as in Fig. 11–32b. When the end is fixed to a support, as in Fig. 11–32a, the pulse reaching that fixed end exerts a force (upward) on the support. The support exerts an equal but opposite force downward on the rope (Newton's third law). This downward force on the rope is what "generates" the inverted reflected pulse.

Consider next a pulse that travels down a rope which consists of a light section and a heavy section, as shown in Fig. 11–33. When the wave pulse reaches the boundary between the two sections, part of the pulse is reflected and part is transmitted, as shown. The heavier the second section of rope, the less the energy that is transmitted. (When the second section is a wall or rigid support, very little is transmitted and most is reflected, as in Fig. 11–32a.) For a periodic wave, the frequency of the transmitted wave does not change across the boundary because the boundary point oscillates at that frequency. Thus if the transmitted wave has a lower speed, its wavelength is also shorter ($\lambda = v/f$).

FIGURE 11–33 When a wave pulse traveling to the right along a thin cord (a) reaches a discontinuity where the rope becomes thicker and heavier, then part is reflected and part is transmitted (b).