ADVANCED TOPICS

See “De Broglie Waves” in **Appendix J: Advanced Topics** to learn about the wave characteristics that all matter exhibits at the microscopic level.

## REFLECTION

In our discussion of waves so far, we have assumed that the waves being analyzed could travel indefinitely without striking anything that would stop them or otherwise change their motion. But what happens to the motion of a wave when it reaches a boundary?

### At a free boundary, waves are reflected

Consider a pulse wave traveling on a stretched rope whose end forms a ring around a post, as shown in **Figure 19(a).** We will assume that the ring is free to slide along the post without friction.

As the pulse travels to the right, each point of the rope moves up once and then back down. When the pulse reaches the boundary, the rope is free to move up as usual, and it pulls the ring up with it. Then, the ring is pulled back down by the tension in the rope. The movement of the rope at the post is similar to the movement that would result if someone were to whip the rope upward to send a pulse to the left, which would cause a pulse to travel back along the rope to the left. This is called *reflection.* Note that the reflected pulse is upright and has the same amplitude as the incident pulse.

### At a fixed boundary, waves are reflected and inverted

Now consider a pulse traveling on a stretched rope that is fixed at one end, as in **Figure 19(b).** When the pulse reaches the wall, the rope exerts an upward force on the wall, and the wall in turn exerts an equal and opposite reaction force on the rope. This downward force on the rope causes a displacement in the direction opposite the displacement of the original pulse. As a result, the pulse is inverted after reflection.

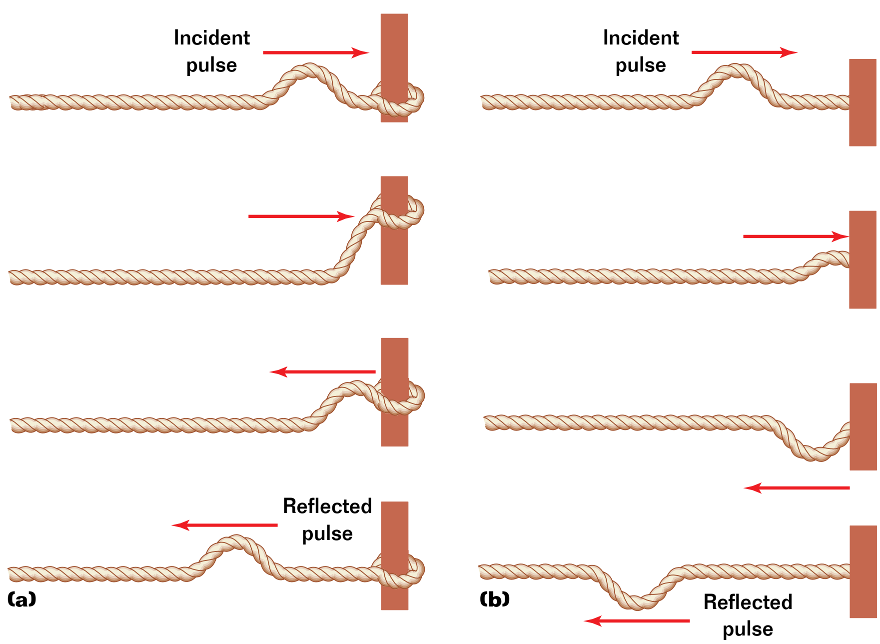


**Figure 19**
**(a)** When a pulse travels down a rope whose end is free to slide up the post, the pulse is reflected from the free end. **(b)** When a pulse travels down a rope that is fixed at one end, the reflected pulse is inverted.