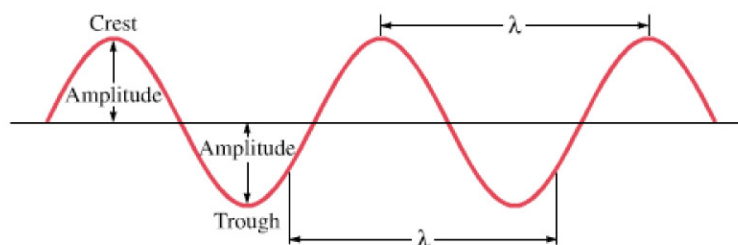


**FIGURE 11–23** Characteristics of a single-frequency continuous wave.



*Amplitude,  $A$*

*Wavelength,  $\lambda$*

*Frequency,  $f$*

*Period,  $T$*

*Wave velocity*

Some of the important quantities used to describe a periodic sinusoidal wave are shown in Fig. 11–23. The high points on a wave are called *crests*; the low points, *troughs*. The **amplitude**,  $A$ , is the maximum height of a crest, or depth of a trough, relative to the normal (or equilibrium) level. The total swing from a crest to a trough is twice the amplitude. The distance between two successive crests is called the **wavelength**,  $\lambda$  (the Greek letter lambda). The wavelength is also equal to the distance between *any* two successive identical points on the wave. The **frequency**,  $f$ , is the number of crests—or complete cycles—that pass a given point per unit time. The **period**,  $T$ , equals  $1/f$  and is the time elapsed between two successive crests passing by the same point in space.

The **wave velocity**,  $v$ , is the velocity at which wave crests (or any other part of the waveform) move. The wave velocity must be distinguished from the velocity of a particle of the medium itself as we saw in Example 11–10.

A wave crest travels a distance of one wavelength,  $\lambda$ , in a time equal to one period,  $T$ . Thus the wave velocity is  $v = \lambda/T$ . Then, since  $1/T = f$ ,

$$v = \lambda f \text{ (sinusoidal waves)}$$

$$v = \lambda f.$$

**(11–12)**

For example, suppose a wave has a wavelength of 5 m and a frequency of 3 Hz. Since three crests pass a given point per second, and the crests are 5 m apart, the first crest (or any other part of the wave) must travel a distance of 15 m during the 1 s. So its speed is 15 m/s.

The magnitude of the velocity of a wave, or its speed, depends on the properties of the medium in which it travels. The speed of a wave on a stretched string or cord, for example, depends on the tension in the cord,  $F_T$ , and on the cord's mass per unit length,  $m/L$ . For waves of small amplitude, the relationship is

*Speed of  
wave on a cord*

$$v = \sqrt{\frac{F_T}{m/L}}.$$

**(11–13)**

This formula makes sense qualitatively on the basis of Newtonian mechanics. That is, we expect the tension to be in the numerator and the mass per unit length in the denominator. Why? Because when the tension is greater, we expect the velocity to be greater since each segment of cord is in tighter contact with its neighbor; and the greater the mass per unit length, the more inertia the cord has and the more slowly the wave would be expected to propagate.

**EXAMPLE 11–11 Wave on a wire.** A wave whose wavelength is 0.30 m is traveling down a 300-m-long wire whose total mass is 15 kg. If the wire is under a tension of 1000 N, what are the speed and frequency of this wave?

**APPROACH** We assume the velocity of this wave on a wire is given by Eq. 11–13. We get the frequency from Eq. 11–12,  $f = v/\lambda$ .

**SOLUTION** From Eq. 11–13, the velocity is

$$v = \sqrt{\frac{1000 \text{ N}}{(15 \text{ kg})/(300 \text{ m})}} = \sqrt{\frac{1000 \text{ N}}{(0.050 \text{ kg/m})}} = 140 \text{ m/s}.$$

The frequency is

$$f = \frac{v}{\lambda} = \frac{140 \text{ m/s}}{0.30 \text{ m}} = 470 \text{ Hz}.$$

**NOTE** A higher tension would increase both  $v$  and  $f$ , whereas a thicker, denser wire would reduce  $v$  and  $f$ .