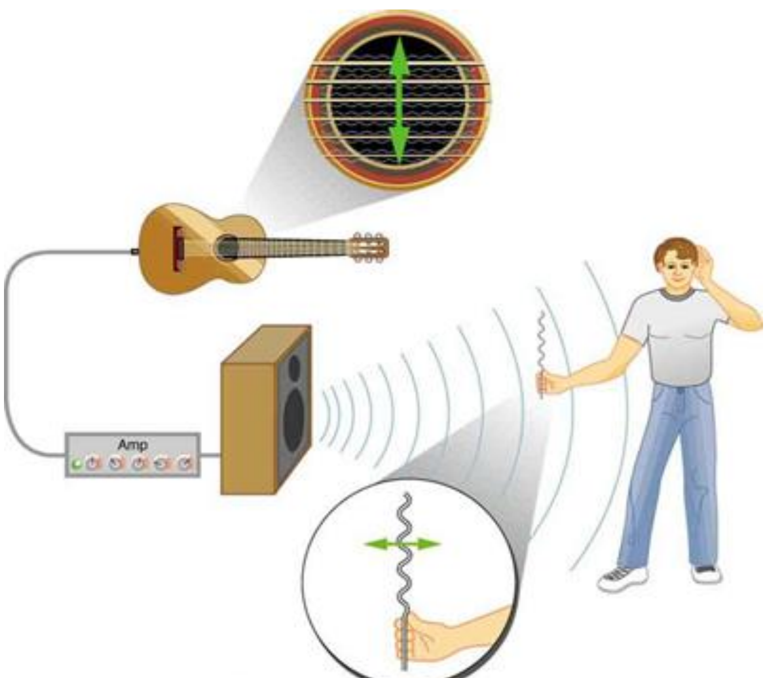
# Chapter 16

# Waves-I

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## 16.2 Types of Waves

1. ***Mechanical waves.*** These waves have two central features: They are governed by Newton's laws, and they can exist only within a material medium, such as water, air, and rock. Common examples include water waves, sound waves, and seismic waves.

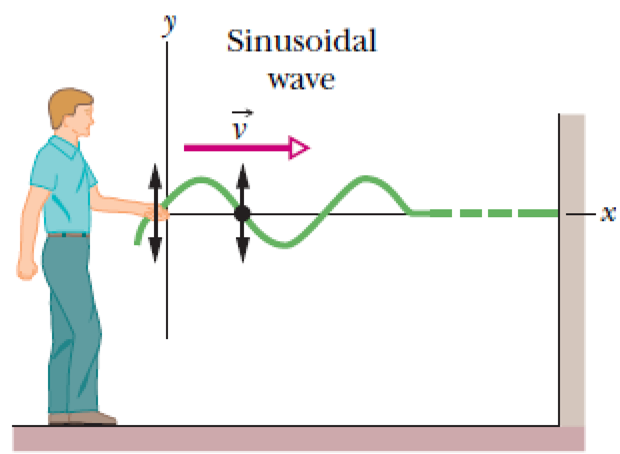
2. ***Electromagnetic waves.*** waves. These waves require no material medium to exist. All electromagnetic waves travel through a vacuum at the same exact speed *c= 299,79,458 m/s*. *C*ommon examples include visible and ultraviolet light, radio and television waves, microwaves, x rays, and radar.

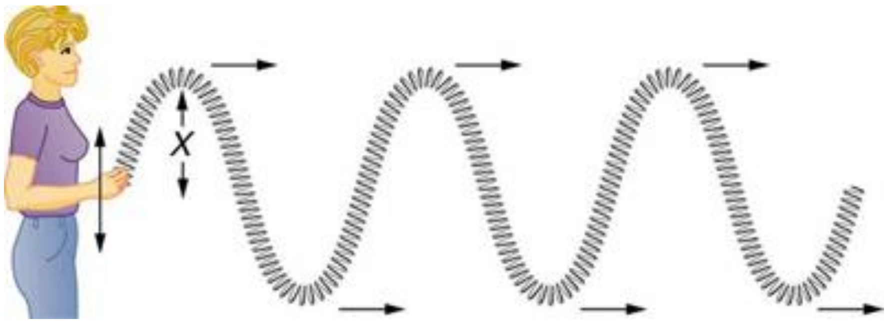
3. ***Matter waves.*** These waves are associated with electrons, protons, and other fundamental particles, and even atoms and molecules. These waves are also called matter waves.

## 16.3 Transverse and Longitudinal Waves

In a transverse wave, the displacement of every such oscillating element along the wave is perpendicular to the direction of travel of the wave, as indicated in Fig. 16-1.

Fig. 16-1




In a longitudinal wave the motion of the oscillating particles is parallel to the direction of the wave's travel, as shown in Fig. 16-2.

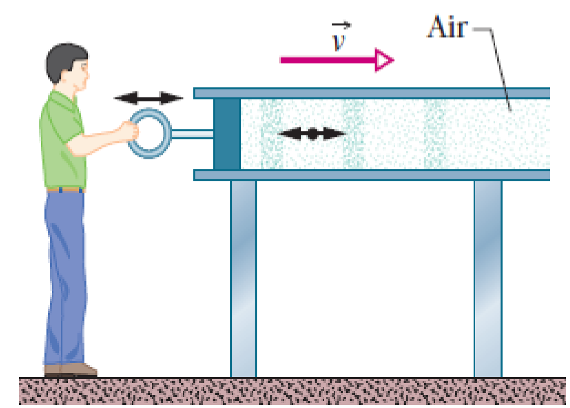
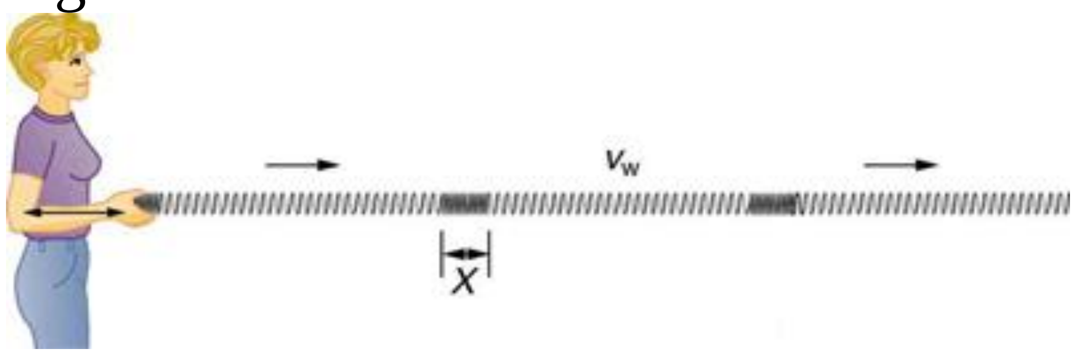



Fig. 16-2



# 16.4 Wave variables

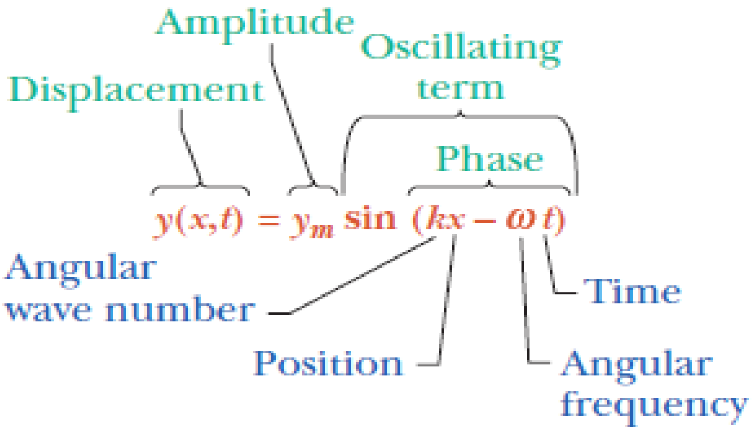



**Fig. 16-3** The names of the quantities in Eq. 16-2, for a transverse sinusoidal wave.

• The **frequency** $f$ of a wave is defined as 1/T and is related to the angular frequency $\omega$ by

$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$

• A **phase constant ϕ in the wave function:** $y = y_m \sin(kx - \omega t + \phi)$. The value of $\phi$ can be chosen so that the function gives some other displacement and slope at $x$ 0 *when* $t$ 0.

• The **amplitude** $y_m$ of a wave is the magnitude of the maximum displacement of the elements from their equilibrium positions as the wave passes through them.

• The **phase of the wave** is the argument $(kx - \omega t)$ of the sine function. As the wave sweeps through a string element at a particular position x, the phase changes linearly with time t.

• The **wavelength** $\lambda$ of a wave is the distance parallel to the direction of the wave's
•travel) between repetitions of the shape of the wave (or wave shape). It is related to the angular wave number, $k$, by

$$k = \frac{2\pi}{\lambda} \quad \text{(angular wave number).}$$

• The **period of oscillation** $T$ of a wave is the time for an element to move through one full oscillation. It is related to the angular frequency, $\omega$, by

$$\omega = \frac{2\pi}{T}$$

# 16.4 The Speed of a Traveling Wave

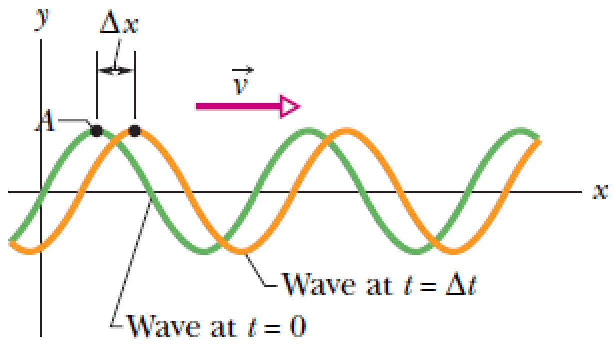



**Fig. 16-7** Two snapshots of the wave of Fig. 16-4, at time $t = 0$ and then at time $t = \Delta t$. As the wave moves to the right at velocity $\vec{v}$, the entire curve shifts a distance $\Delta x$ during $\Delta t$. Point $A$ "rides" with the wave form, but the string elements move only up and down.

As the wave in Fig. 16-7 moves, each point of the moving wave form, such as point A marked on a peak, retains its displacement y. (Points on the string do not retain their displacement, but points on the wave form do.) If point A retains its displacement as it moves, the phase giving it that displacement must remain a constant:

$$kx - \omega t = \text{a constant.}$$

$$k\frac{dx}{dt} - \omega = 0$$

$$\frac{dx}{dt} = v = \frac{\omega}{k}.$$

$$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f \quad \text{(wave speed).}$$

## Sample Problem

### Transverse wave, amplitude, wavelength, period, velocity

A wave traveling along a string is described by

$$y(x, t) = 0.00327 \sin(72.1x - 2.72t), \qquad (16\text{-}18)$$

in which the numerical constants are in SI units (0.00327 m, 72.1 rad/m, and 2.72 rad/s).

(a) What is the amplitude of this wave?

(b) What are the wavelength, period, and frequency of this wave?

(c) What is the velocity of this wave?

(d) What is the displacement $y$ of the string at $x = 22.5$ cm and $t = 18.9$ s?

## Sample Problem

### Transverse wave, transverse velocity, transverse acceleration

In the preceding sample problem, we showed that at $t = 18.9$ s the transverse displacement $y$ of the element of the string at $x = 22.5$ cm due to the wave of Eq. 16-18 is 1.92 mm.

(a) What is $u$, the transverse velocity of the same element of the string, at that time? (This velocity, which is associated with the transverse oscillation of an element of the string, is in the $y$ direction. Do not confuse it with $v$, the constant velocity at which the *wave form* travels along the $x$ axis.)

(b) What is the transverse acceleration $a_y$ of the same element at that time?