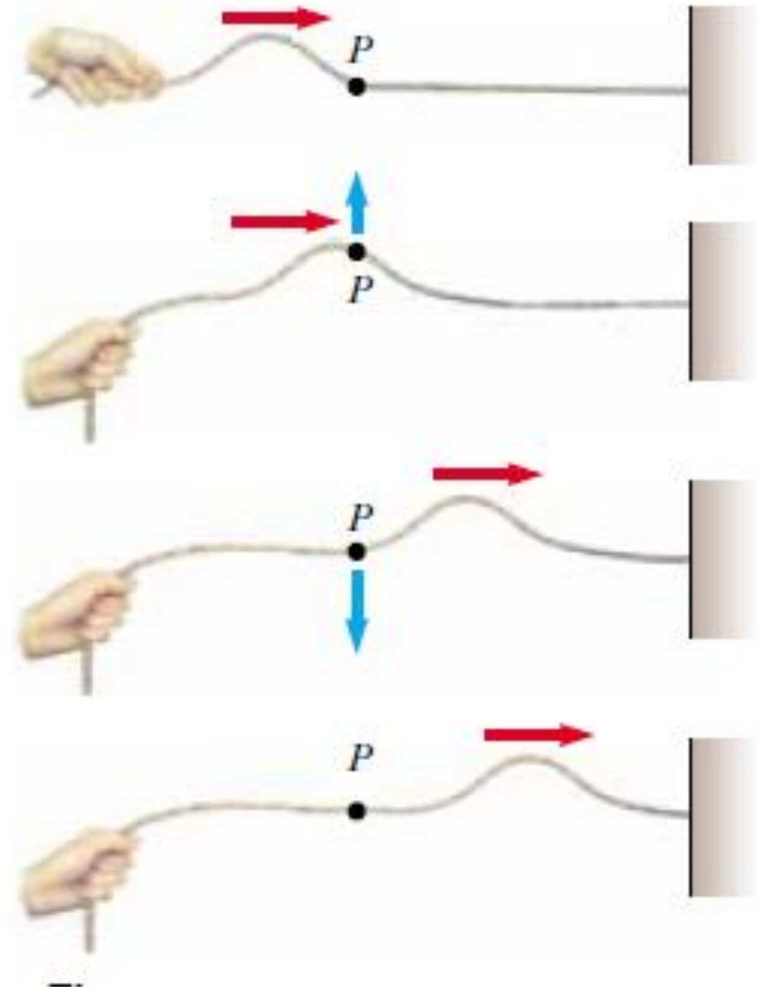
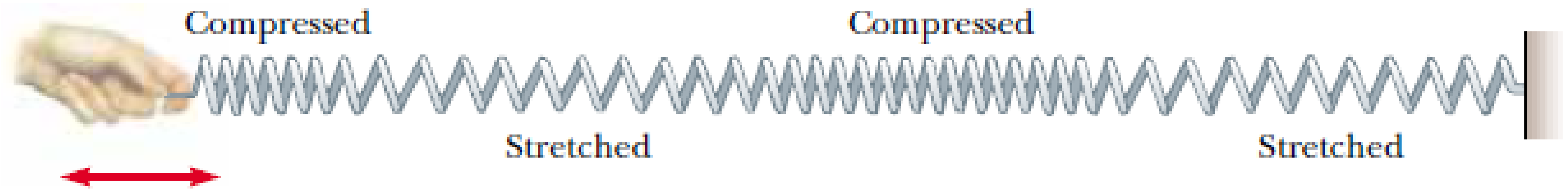
Gelombang

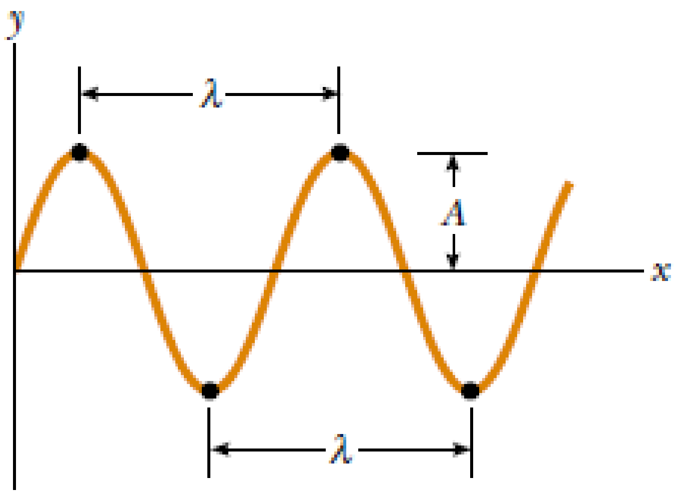
Gelombang yang merambat dan menyebabkan bagian dari media yang diganggu, untuk bergerak tegak lurus arah perambatan disebut **gelombang transversal**.



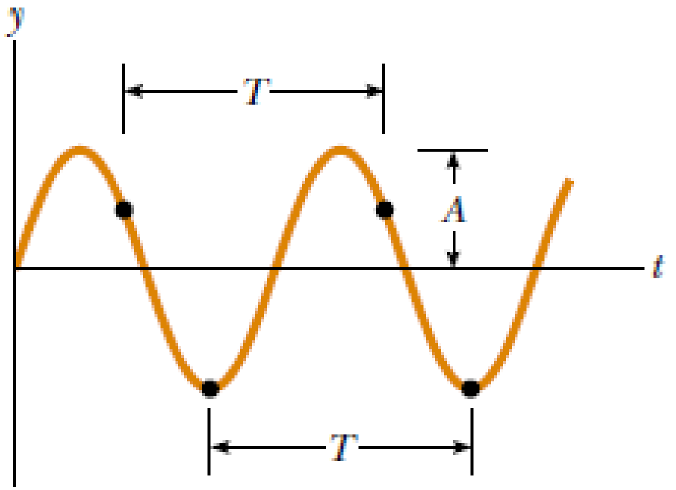
Gelombang yang merambat dan menyebabkan bagian dari medium bergerak sejajar arah perambatan disebut **gelombang longitudinal**.



Sinusoidal Waves



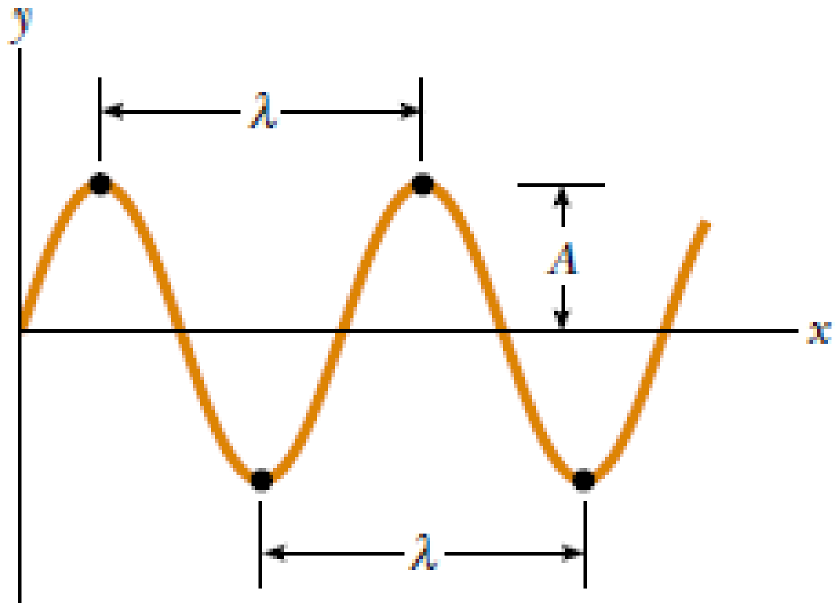
(a)



(b)

Panjang gelombang (λ)

Adalah jarak terpendek antara 2 titik yang identik pada posisi gelombang yang berdekatan.



Periode (T)

Adalah interval waktu yang dibutuhkan untuk 2 titik identik yang berdekatan untuk melewati suatu titik.

Frekuensi (f)

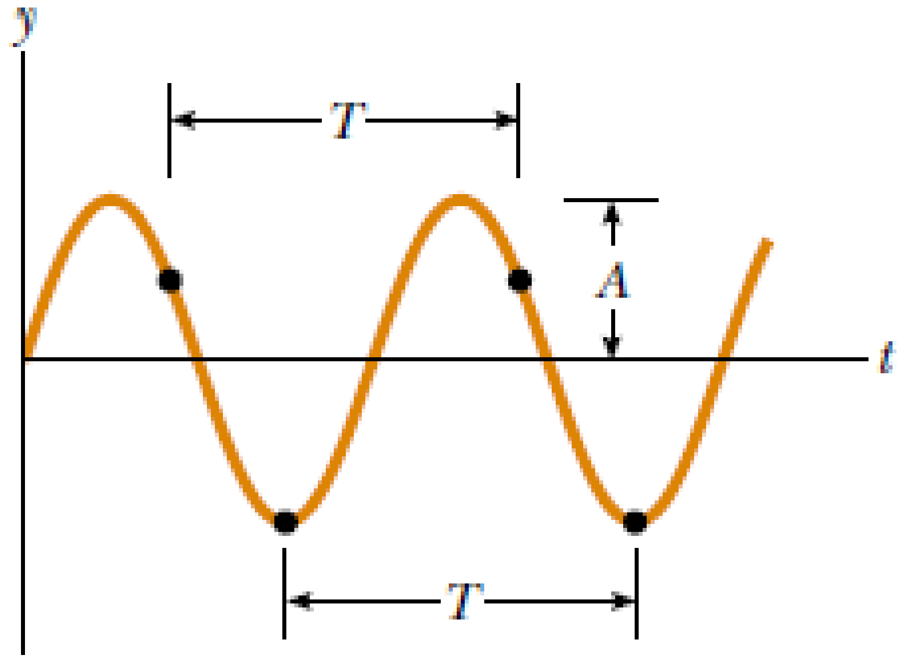
Frekuensi dari suatu periode gelombang adalah jumlah puncak yang melewati suatu titik dalam satu satuan interval waktu.

$$f = \frac{1}{T}$$

Satuan yang umum untuk frekuensi adalah second^{-1} atau hertz (Hz). Satuan T adalah seconds.

Amplitudo (A)

Adalah pergeseran maksimal dari kondisi kesetimbangan suatu bagian medium.



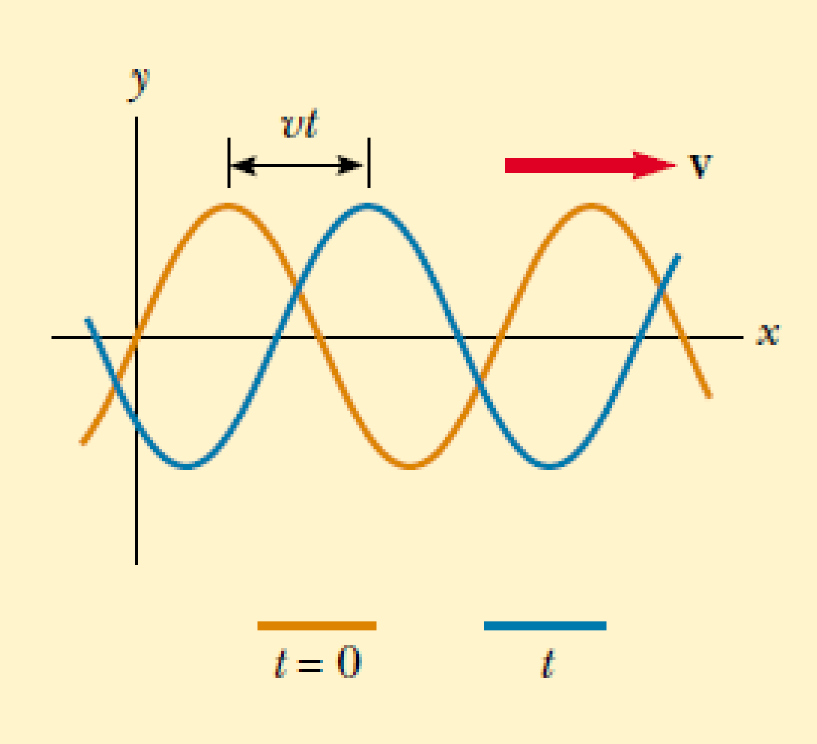
$$y(x, t) = A \sin\left[\frac{2\pi}{\lambda}(x - vt)\right]$$

$$k \equiv \frac{2\pi}{\lambda}$$

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

$$v = \frac{\lambda}{T}$$

$$y = A \sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right]$$



$$y = A \sin(kx - \omega t)$$

$$y = A\sin(kx - \omega t)$$

$$v = \frac{\omega}{k}$$

$$v = \lambda f$$

$$y = A\sin(kx - \omega t + \phi)$$

dengan ϕ adalah konstanta fasa.

Ex 1.

A sinusoidal wave traveling in the positive *x* direction has an amplitude of 15.0 cm, a wavelength of 40.0 cm, and a frequency of 8.00 Hz. The vertical position of an element of the medium at $t = 0$ and $x = 0$ is also 15.0 cm

a) Find the wave number *k*, period *T*, angular frequency ω, and speed *v* of the wave.

b) Determine the phase constant ϕ, and write a general expression for the wave function.

$$k = \frac{2\pi}{\lambda} = \frac{2\pi \text{ rad}}{40.0 \text{ cm}} = \boxed{0.157 \text{ rad/cm}}$$

$$T = \frac{1}{f} = \frac{1}{8.00 \text{ s}^{-1}} = \boxed{0.125 \text{ s}}$$

$$\omega = 2\pi f = 2\pi(8.00 \text{ s}^{-1}) = \boxed{50.3 \text{ rad/s}}$$

$$v = \lambda f = (40.0 \text{ cm})(8.00 \text{ s}^{-1}) = \boxed{320 \text{ cm/s}}$$

Solution Because $A = 15.0$ cm and because $y = 15.0$ cm at $x = 0$ and $t = 0$, substitution into $y = A\sin(kx - \omega t + \phi)$ gives :

$$15.0 = (15.0)\sin\phi \qquad \text{or} \qquad \sin\phi = 1$$

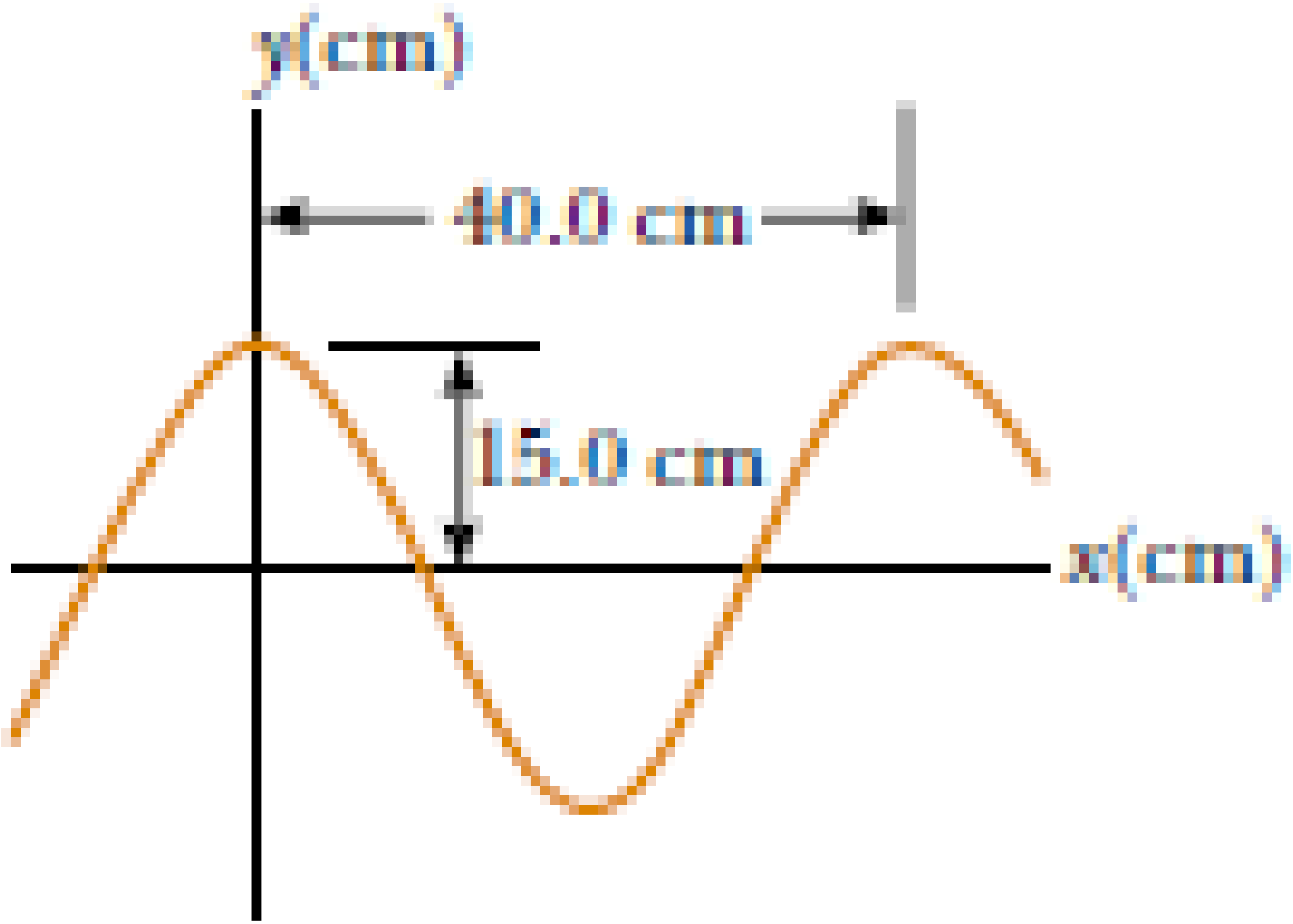
We may take the principal value $\phi = \pi/2$ rad (or 90°). Hence, the wave function is of the form

$$y = A\sin\left(kx - \omega t + \frac{\pi}{2}\right) = A\cos(kx - \omega t)$$

get

By inspection, we can see that the wave function must have this form, noting that the cosine function has the same shape as the sine function displaced by 90°. Substituting the values for A, k, and ω into this expression, we obtain

$$y = (15.0\text{ cm})\cos(0.157x - 50.3t)$$


y(cm)
40.0 cm
15.0 cm
x(cm)

Ex. 2

A wave traveling along a string is described by

$$y(x, t) = 0.00327 \sin(72.1x - 2.72t).$$

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?

a. We see that

$$y_m = 0.00327 \text{ m} = 3.27 \text{ mm}. \qquad \text{(Answer)}$$

b.

$$k = 72.1 \text{ rad/m} \quad \text{and} \quad \omega = 2.72 \text{ rad/s}.$$

We then relate wavelength λ to k via Eq. 16-5:

$$\lambda = \frac{2\pi}{k} = \frac{2\pi \text{ rad}}{72.1 \text{ rad/m}}$$
$$= 0.0871 \text{ m} = 8.71 \text{ cm}. \qquad \text{(Answer)}$$

Next, we relate T to ω with Eq. 16-8:

$$T = \frac{2\pi}{\omega} = \frac{2\pi \text{ rad}}{2.72 \text{ rad/s}} = 2.31 \text{ s}, \qquad \text{(Answer)}$$

and from Eq. 16-9 we have

$$f = \frac{1}{T} = \frac{1}{2.31 \text{ s}} = 0.433 \text{ Hz}. \qquad \text{(Answer)}$$

c.

Calculation: The speed of the wave is given by Eq. 16-13:

$$v = \frac{\omega}{k} = \frac{2.72 \text{ rad/s}}{72.1 \text{ rad/m}} = 0.0377 \text{ m/s}$$
$$= 3.77 \text{ cm/s.} \qquad \text{(Answer)}$$

d.

$$y = 0.00327 \sin(72.1 \times 0.225 - 2.72 \times 18.9)$$
$$= (0.00327 \text{ m}) \sin(-35.1855 \text{ rad})$$
$$= (0.00327 \text{ m})(0.588)$$
$$= 0.00192 \text{ m} = 1.92 \text{ mm.} \qquad \text{(Answer)}$$

Osilasi

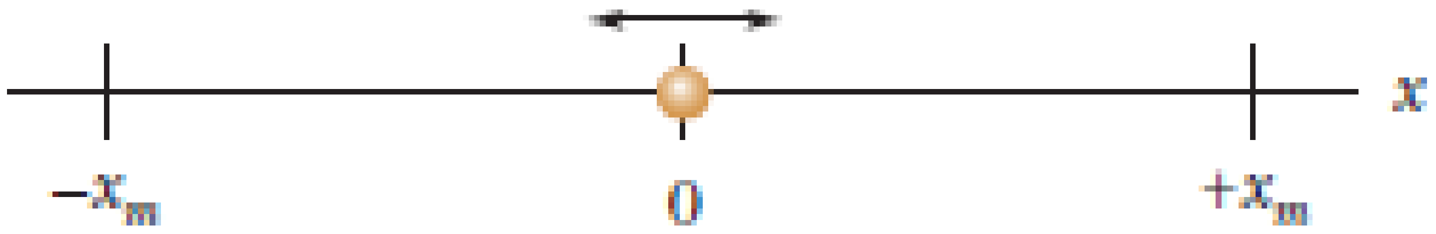


Figure 15-1 A particle repeatedly oscillates left and right along an x axis, between extreme points x_m and $-x_m$.

Frekuensi osilasi

$$1 \text{ hertz} = 1 \text{ Hz} = 1 \text{ oscillation per second} = 1 \text{ s}^{-1}.$$

$$T = \frac{1}{f}.$$

Simple harmonic motion

$$x(t) = x_m \cos(\omega t + \phi) \quad \text{(displacement)},$$

X max = amplitudo

Ex. 3

An object oscillates with simple harmonic motion along the *x* axis. Its position varies with time according to the equation

$$x = (4.00\text{ m})\cos\left(\pi t + \frac{\pi}{4}\right)$$

where *t* is in seconds and the angles in the parentheses are in radians.

a) Determine the amplitude, frequency, and period of the motion.
b) Calculate the velocity and acceleration of the object at any time *t*.
c) Using the results of part (b), determine the position, velocity, and acceleration of the object at *t* = 1.00 s.
d) Determine the maximum speed and maximum acceleration of the object.
e) Find the displacement of the object between *t* = 0 and *t* = 1.00 s.

a. ***Solution*** By comparing this equation with Equation 15.6, $x = A\cos(\omega t + \phi)$, we see that $A =$ 4.00 m and $\omega = \pi$ rad/s. Therefore, $f = \omega/2\pi = \pi/2\pi =$ 0.500 Hz and $T = 1/f =$ 2.00 s.

b. ***Solution*** Differentiating x to find v, and v to find a, we obtain

$$v = \frac{dx}{dt} = -(4.00\text{ m/s})\sin\left(\pi t + \frac{\pi}{4}\right)\frac{d}{dt}(\pi t)$$

$$= -(4.00\pi\text{ m/s})\sin\left(\pi t + \frac{\pi}{4}\right)$$

$$v = -\omega x_m \sin(\omega t + \phi) \quad \text{(velocity)}$$

$$a = -\omega^2 x_m \cos(\omega t + \phi) \quad \text{(acceleration).}$$

$$a = \frac{dv}{dt} = -(4.00\pi\text{ m/s})\cos\left(\pi t + \frac{\pi}{4}\right)\frac{d}{dt}(\pi t)$$

$$= -(4.00\pi^2\text{ m/s}^2)\cos\left(\pi t + \frac{\pi}{4}\right)$$

c. **Solution** Noting that the angles in the trigonometric functions are in radians, we obtain, at $t = 1.00$ s,

$$x = (4.00 \text{ m}) \cos\left(\pi + \frac{\pi}{4}\right) = (4.00 \text{ m}) \cos\left(\frac{5\pi}{4}\right)$$

$$= (4.00 \text{ m})(-0.707) = \boxed{-2.83 \text{ m}}$$

d. **Solution** In the general expressions for v and a found in part (B), we use the fact that the maximum values of the sine and cosine functions are unity. Therefore, v varies between $\pm 4.00\pi$ m/s, and a varies between $\pm 4.00\pi^2$ m/s^2. Thus,

$$v_{max} = 4.00\pi \text{ m/s} = \boxed{12.6 \text{ m/s}}$$

$$a_{max} = 4.00\pi^2 \text{ m/s}^2 = \boxed{39.5 \text{ m/s}^2}$$

We obtain the same results using the relations $v_{max} = \omega A$ and $a_{max} = \omega^2 A$, where $A = 4.00$ m and $\omega = \pi$ rad/s.

e. **Solution** The position at $t = 0$ is

$$x_i = (4.00 \text{ m}) \cos\left(0 + \frac{\pi}{4}\right) = (4.00 \text{ m})(0.707) = 2.83 \text{ m}$$

In part (C), we found that the position at $t = 1.00$ s is -2.83 m; therefore, the displacement between $t = 0$ and $t = 1.00$ s is

$$\Delta x = x_f - x_i = -2.83 \text{ m} - 2.83 \text{ m} = -5.66 \text{ m}$$

HW 1

In an engine, a piston oscillates with simple harmonic motion so that its position varies according to the expression

$$x = (5.00 \text{ cm})\cos(2t + \pi/6)$$

where *x* is in centimeters and *t* is in seconds. At *t* = 0, find (a) the position of the piston, (b) its velocity, and (c) its acceleration. (d) Find the period and amplitude of the motion.

HW 2

The position of a particle is given by the expression $x = (4.00 \text{ m})\cos(3.00\pi t + \pi)$, where x is in meters and t is in seconds. Determine (a) the frequency and period of the motion, (b) the amplitude of the motion, (c) the phase constant, and (d) the position of the particle at $t = 0.250$ s.