Chapter 11

WAVES

Problems

1. Strategy Form a proportion with the intensities, treating the Sun as an isotropic source. Use Eq. (11-1).

Solution Find the intensity of the sunlight that reaches Jupiter.

$$\frac{I_J}{I_E} = \frac{\frac{P}{4\pi r_J^2}}{\frac{P}{4\pi r_E^2}} = \frac{r_E^{\ 2}}{r_J^{\ 2}}, \text{ so } I_J = \left(\frac{r_E}{r_J}\right)^2 I_E = \left(\frac{1}{5.2}\right)^2 (1400\ \text{W/m}^2) = \boxed{52\ \text{W/m}^2}.$$

7. Strategy Refer to the figure. Use the definition of average speed.

Solution

(a) Find the speed.

$$v_x = \frac{\Delta x}{\Delta t} = \frac{1.80\text{ m} - 1.50\text{ m}}{0.20\text{ s}} = 1.5\text{ m/s}$$

Find the position.

$$x_f = x_i + v\Delta t = 1.80\text{ m} + (1.5\text{ m/s})(3.00\text{ s} - 0.20\text{ s}) = \boxed{6.0\text{ m}}$$

(b) $$t_f = \frac{x_f - x_i}{v_x} + t_i = \frac{4.00\text{ m} - 1.80\text{ m}}{1.5\text{ m/s}} + 0.20\text{ s} = \boxed{1.7\text{ s}}$$

17. Strategy Use Eq. (11-6).

Solution Find the frequency with which the buoy bobs up and down.

$$f = \frac{v}{\lambda} = \frac{2.5\text{ m/s}}{7.5\text{ m}} = \boxed{0.33\text{ Hz}}$$

29. (a) Strategy Substitute t = 0, 0.96 s, and 1.92 s into $y(x, t) = (0.80\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x - (\pi/6.0\text{ s}^{-1})t]$ and graph the resulting equations.

Solution The three equations are:

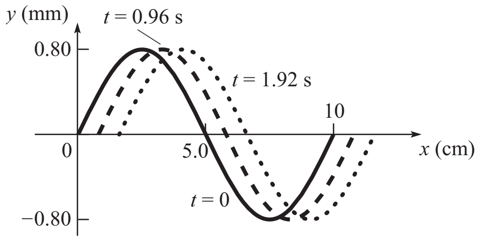
$y(x, 0) = (0.80\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x]$, $y(x, 0.96\text{ s}) = (0.80\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x - 0.50]$, and $y(x, 1.92\text{ s}) = (0.80\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x - 1.0]$.

Find the wavelength.

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{\pi/(5.0\text{ cm})} = 10\text{ cm}$$

The amplitude of the wave is A = 0.80 mm. The first graph (solid) begins at the origin. The second graph (dashed) is shifted to the right by $(5.0\text{ cm} \times 0.50)/\pi = 0.80\text{ cm}.$ The third graph (dotted) is shifted to the right twice as far as the second graph, or 1.6 cm.

The graphs are shown:

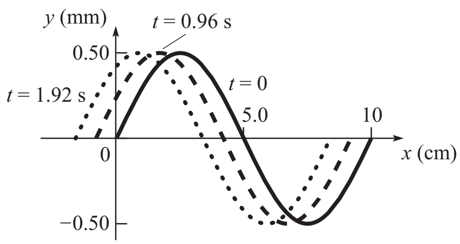


(b) Strategy Substitute $t = 0$, 0.96 s, and 1.96 s into $y(x, t) = (0.50\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x + (\pi/6.0\text{ s}^{-1})t]$ and graph the resulting equations.

Solution The three equations are:
$y(x, 0) = (0.50\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x]$, $y(x, 0.96\text{ s}) = (0.50\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x + 0.50]$, and
$y(x, 1.92\text{ s}) = (0.50\text{ mm})\sin[(\pi/5.0\text{ cm}^{-1})x + 1.0]$.
Find the wavelength.

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{\pi/(5.0\text{ cm})} = 10\text{ cm}$$

The amplitude of the wave is $A = 0.50$ mm. The first graph (solid) begins at the origin. The second graph (dashed) is shifted to the left by $(5.0\text{ cm} \times 0.50)/\pi = 0.80\text{ cm}$. The third graph (dotted) is shifted to the left twice as far as the second graph, or 1.6 cm. The graphs are shown:



(c) Strategy Refer to the results of parts (a) and (b).

Solution The graphs obtained in part (a) move to the right as time progresses, so $\boxed{y(x, t) = (0.80\text{ mm})\sin(kx - \omega t)\text{ represents a wave traveling in the } +x\text{-direction}}$. The graphs obtained in part (b) move to the left as time progresses, so $\boxed{y(x, t) = (0.50\text{ mm})\sin(kx + \omega t)\text{ represents a wave traveling in the } -x\text{-direction}}$.

37. Strategy Refer to the figure. Use $\Delta x = v_x \Delta t$ and the principle of superposition.

Solution The pulse moves 1.80 m − 1.50 m = 0.30 m in 0.20 s. So, the speed of the wave is $v = \frac{0.30\text{ m}}{0.20\text{ s}} = 1.5\text{ m/s}$. When the pulse reaches the right endpoint, it is reflected and inverted. When exactly half of the pulse has been reflected and inverted, the superposition of the incident and reflected waves results in the cancellation of the waves $(y_1 + y_2 = 0)$. Thus, the string looks flat at $t = \frac{x}{v} = \frac{4.0\text{ m} - 1.5\text{ m}}{1.5\text{ m/s}} = \boxed{1.7\text{ s}}$.

49. Strategy The frequencies are given by $f_n = nv/(2L)$. The speed of the transverse waves is related to the tension by $v = \sqrt{T/\mu}$.

Solution

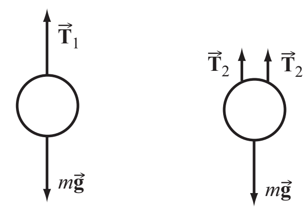
(a) Find the frequency of the fundamental oscillation.

$$f_1 = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{T}{\mu}} = \frac{1}{2(1.5\text{ m})}\sqrt{\frac{12\text{ N}}{1.2\times10^{-3}\text{ kg/m}}} = \boxed{33\text{ Hz}}$$

(b) Find the tension.

$$f_3 = \frac{3v}{2L} = \frac{3}{2L}\sqrt{\frac{T}{\mu}},\text{ so } T = \frac{4\mu L^2 f_3^{\,2}}{9} = \frac{4(1.2\times10^{-3}\text{ kg/m})(1.5\text{ m})^2(0.50\times10^3\text{ Hz})^2}{9} = \boxed{300\text{ N}}.$$

65. Strategy Even though the wire is cut in two, the linear mass density does not change (half the length and half the mass). According to Eq. (11-4), the speed of waves on a wire is directly proportional to the square root of the tension. According to Eq. (11-13), the frequency of the waves on a wire is directly proportional to the speed of the waves. Therefore, the frequency is directly proportional to the square root of the tension in a wire. Use Newton's second law.



Solution For the single wire:
$\Sigma F_y = T_1 - mg = 0$, so $T_1 = mg$.
For the two wires:
$\Sigma F_y = 2T_2 - mg = 0$, so $T_2 = mg/2$.
Therefore, $T_1 = 2T_2$. Form a proportion.

$$\frac{f_2}{f_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{T_2}{2T_2}} = \frac{1}{\sqrt{2}},\text{ so } f_2 = \frac{f_1}{\sqrt{2}}.$$

Thus, the new fundamental frequency of each wire is $660\text{ Hz}/\sqrt{2} = \boxed{470\text{ Hz}}$.