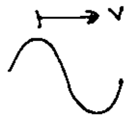
16.7  $v = 80$ m/s moving positive x-direction.

$\boxed{1}$ At $t=0$ and $x=0$ $y = 0.04$ m
and $v_y = 0$ m/s

$\boxed{2}$ Maximum transverse speed is
$v_y = 16$ m/s at $x = 0$

The wave function will be

$$y = A \sin(kx \underbrace{- \omega t}_{\text{moving toward } +x \text{ axis}} + \phi)$$

and

$$v_y = \frac{dy}{dt} = \omega A \cos(kx - \omega t + \phi)$$

From $\boxed{2}$ we know $\omega A = 16$ m/s

From $\boxed{1}$ we know

$$y = 0.04 = A \sin(0 - 0 + \phi)$$

$$v_y = 0 = \omega A \cos(0 - 0 + \phi)$$

So $\cos\phi = 0 \rightarrow \phi = \pm 90^\circ$

then $0.04 = A \sin(\pm 90^\circ)$

we must chose (+) and then

$$A = 0.04$$

The ω can then be determined

$$\omega A = 16 \text{ m/s}$$

$$\omega (0.04) = 16$$

$$\omega = 400 \text{ rad/s}$$

From this $\omega = 2\pi f$

$$400 = 2\pi f$$

$$f = 63.7 \text{ Hz}$$

Then we can go after λ:

$$f\lambda = v$$

$$63.7 \lambda = 80 \text{ m/s}$$

$$\lambda = 1.256 \text{ m}$$

And then

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{1.256} = 5 \text{ m}^{-1}$$

16.15

$T = 10$ Newtons

$\mu = 5\ \frac{g}{cm} = \frac{5\times10^{-3}\ kg}{0.01\ m}$

$= 5\times10^{-5}\ kg/m$

Amplitude $= 0.12$ mm

$= 0.12\times10^{-3}$ m

$f = 100$ Hz $\longrightarrow \omega = 2\pi f = 2\pi\, 100 = 628$ rad/s

traveling down $-x$ axis

Can get $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{10}{5\times10^{-5}}} = 4.47\times10^2$ m/s

then $f\lambda = v$

$100\,\lambda = 4.47\times10^2$

$\lambda = 4.47$ m

then $k = \frac{2\pi}{\lambda} = \frac{2\pi}{4.47} = 1.404\ m^{-1}$

Since the wave is going down $-x$ axis

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

16.19

$T = 500$ Newtons

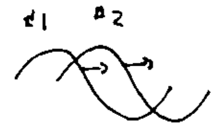
$\mu = \frac{60 g}{2 m} = \frac{0.060 kg}{2 m}$

$= 0.030$ kg/m

$V = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{500}{0.030}}$

$= 129$ m/s

16.31



$\phi = \pi/2$

$y_1 = A\sin(kx - \omega t)$ $\quad y_2 = A\sin(kx - \omega t + \phi)$

Adding these

$y_{TOT} = y_1 + y_2 = \underbrace{2A\cos\frac{\phi}{2}}_{\text{New amplitude}}\ \sin(kx - \omega t + \phi/2)$

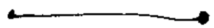
New amplitude $= 2A\cos\left(\frac{\pi/2}{2}\right)$

$= 2A\cos(\pi/4)$

$= \frac{2}{\sqrt{2}}A$

$= \sqrt{2}A$

16.43.



$T = 250$ Newtons

$L = 10$ m

$\mu = \frac{100\text{ gm}}{10\text{ m}} = \frac{0.1\text{ kg}}{10\text{ m}}$

$= 0.01$ kg/m

$V = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{250}{0.01}} = 158.1$ m/s

n=1  $\lambda_1 = 20$ m $f_1 = \frac{v}{\lambda_1} = \frac{158.1}{20} =$

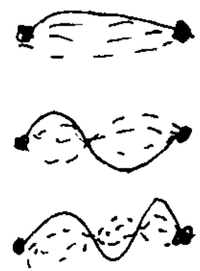
$= 79$ Hz

n=2  $\lambda_2 = \frac{\lambda_1}{2} = 10$ m $f_2 = 2f_1 = 158$ Hz

 $\lambda_3 = \frac{\lambda_1}{3} = 6.67$ m $f_3 = 3f_1 = 237$ Hz

16.45

— L — $L = 75$ cm $= 0.75$ m



λ_1 f_1

we aren't told which harmonics 420 and 315 Hz are.

However since $f_n = nf_1$, the spacing between adjacent harmonics must ~~be~~ the same as f_1

so $f_1 = 105$ Hz

From the string drawing

$\lambda_1 = 2L = 2(0.75) = 1.5$ m

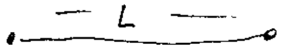
And then

$f_1 \lambda_1 = v$

$105\,(1.5) = v$

$v = 157.5$ m/s

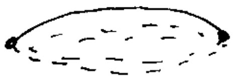
16.48



$\mu = 3.35 \text{ kg/m}$

$T = 65.2 \times 10^6$ Newtons

$L = 347$ m



$\lambda_1 = 2L = 2(347)$
$= 694$ m

$V = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{65.2 \times 10^6}{3.35}} = 4.41 \times 10^3$ m/s

And then

$f_1 \lambda_1 = v$

$f_1\, 694 = 4.41 \times 10^3$

$f_1 = 6.36$ Hz

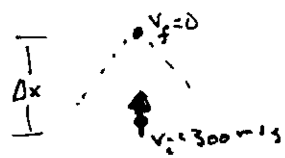
Since $f_n = n f_1$, the frequency spacing between adject nodes is 6.36 Hz

16.88 In the picture there are two features, 1) the thinning of the fabric and the 2) transverse distortion of the indentation.

The picture is taken after $40 \mu s = 40 \times 10^{-6}$ sec

The longitudinal ~~distortion~~ wave causes the thinning of the fabric. In $40 \mu s$, it has traveled $(2000 \text{ m/s})(40 \mu s)$
$= 8 \times 10^{-2}$ m $= 8$ cm

The dent forms over a time $40 \mu s$ because the projectile is stopped from an initial speed 300 m/s. Estimate the depth of the dent by



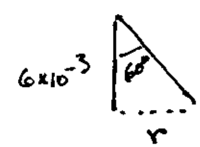
$v_f^2 - v_i^2 = 2a\Delta x$

$a = \frac{\Delta v}{\Delta t} = \frac{-300}{40 \times 10^{-6}} = -7.5 \times 10^6$

$0^2 - 300^2 = 2(-7.5 \times 10^6)\Delta x$

$\Delta x = 6 \times 10^{-3}$ m

Then do some geometry



$\tan 60° = \frac{r}{6 \times 10^{-3}}$

$\rightarrow r = 1 \times 10^{-2}$ m
$= 1$ cm

Chapter 16

••7 A transverse sinusoidal wave is moving along a string in the positive direction of an x axis with a speed of 80 m/s. At $t = 0$, the string particle at $x = 0$ has a transverse displacement of 4.0 cm from its equilibrium position and is not moving. The maximum transverse speed of the string particle at $x = 0$ is 16 m/s. (a) What is the frequency of the wave? (b) What is the wavelength of the wave? If $y(x, t) = y_m \sin(kx \pm \omega t + \phi)$ is the form of the wave equation, what are (c) y_m, (d) k, (e) ω, (f) ϕ, and (g) the correct choice of sign in front of ω?

•15 SSM WWW A stretched string has a mass per unit length of 5.00 g/cm and a tension of 10.0 N. A sinusoidal wave on this string has an amplitude of 0.12 mm and a frequency of 100 Hz and is traveling in the negative direction of an x axis. If the wave equation is of the form $y(x, t) = y_m \sin(kx \pm \omega t)$, what are (a) y_m, (b) k, (c) ω, and (d) the correct choice of sign in front of ω?

•19 SSM What is the speed of a transverse wave in a rope of length 2.00 m and mass 60.0 g under a tension of 500 N?

•31 SSM Two identical traveling waves, moving in the same direction, are out of phase by $\pi/2$ rad. What is the amplitude of the resultant wave in terms of the common amplitude y_m of the two combining waves?

•43 SSM WWW What are (a) the lowest frequency, (b) the second lowest frequency, and (c) the third lowest frequency for standing waves on a wire that is 10.0 m long, has a mass of 100 g, and is stretched under a tension of 250 N?

•45 SSM ILW A string that is stretched between fixed supports separated by 75.0 cm has resonant frequencies of 420 and 315 Hz, with no intermediate resonant frequencies. What are (a) the lowest resonant frequency and (b) the wave speed?

•48 If a transmission line in a cold climate collects ice, the increased diameter tends to cause vortex formation in a passing wind. The air pressure variations in the vortexes tend to cause the line to oscillate (*gallop*), especially if the frequency of the variations matches a resonant frequency of the line. In long lines, the resonant frequencies are so close that almost any wind speed can set up a resonant mode vigorous enough to pull down support towers or cause the line to *short out* with an adjacent line. If a transmission line has a length of 347 m, a linear density of 3.35 kg/m, and a tension of 65.2 MN, what are (a) the frequency of the fundamental mode and (b) the frequency difference between successive modes?

88 *Body armor.* When a high-speed projectile such as a bullet or bomb fragment strikes modern body armor, the fabric of the armor stops the projectile and prevents penetration by quickly spreading the projectile's energy over a large area. This spreading is done by longitudinal and transverse pulses that move *radially* from the impact point, where the projectile pushes a cone-shaped dent into the fabric. The longitudinal pulse, racing along the fibers of the fabric at speed v_l ahead of the denting, causes the fibers to thin and stretch, with material flowing radially inward into the dent. One such radial fiber is shown in Fig. 16-47*a*. Part of the projectile's energy goes into this motion and stretching. The transverse pulse, moving at a slower speed v_t, is due to the denting. As the projectile increases the dent's depth, the dent increases in radius, causing the material in the fibers to move in the same direction as the projectile (perpendicular to the transverse pulse's direction of travel). The rest of the projectile's energy goes into this motion. All the energy that does not eventually go into permanently deforming the fibers ends up as thermal energy.

Figure 16-47*b* is a graph of speed v versus time t for a bullet of mass 10.2 g fired from a .38 Special revolver directly into body armor. The scales of the vertical and horizontal axes are set by v_s = 300 m/s and t_s = 40.0 μs. Take v_l = 2000 m/s, and assume that the half-angle θ of the conical dent is 60°. At the end of the collision, what are the radii of (a) the thinned region and (b) the dent (assuming that the person wearing the armor remains stationary)?

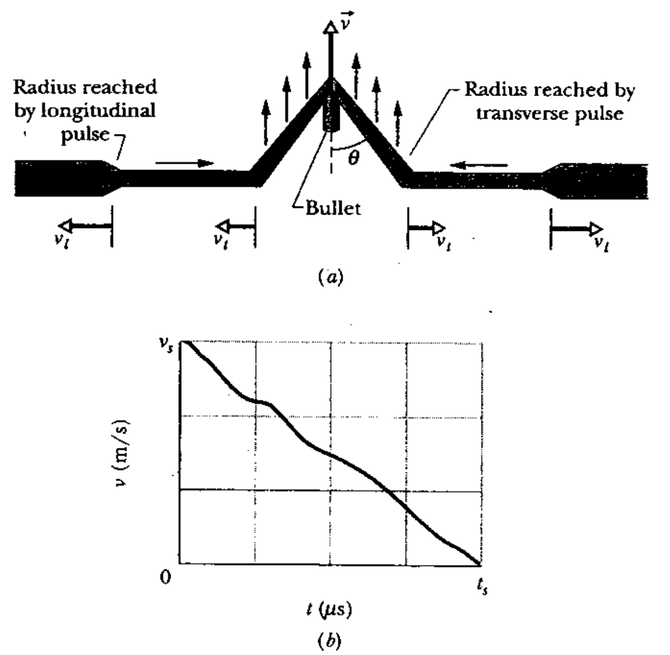


Fig. 16-47 Problem 88.