

18. The volume of a cylinder of height ℓ is $V = \pi r^2 \ell = \pi d^2 \ell / 4$. The strings are long, narrow cylinders, one of diameter d_1 and the other of diameter d_2 (and corresponding linear densities μ_1 and μ_2). The mass is the (regular) density multiplied by the volume: $m = \rho V$, so that the mass-per-unit length is

$$\mu = \frac{m}{\ell} = \frac{\rho \pi d^2 \ell / 4}{\ell} = \frac{\pi \rho d^2}{4}$$

and their ratio is

$$\frac{\mu_1}{\mu_2} = \frac{\pi \rho d_1^2 / 4}{\pi \rho d_2^2 / 4} = \left(\frac{d_1}{d_2} \right)^2.$$

Therefore, the ratio of diameters is

$$\frac{d_1}{d_2} = \sqrt{\frac{\mu_1}{\mu_2}} = \sqrt{\frac{3.0}{0.29}} = 3.2.$$

21. The pulses have the same speed v . Suppose one pulse starts from the left end of the wire at time $t = 0$. Its coordinate at time t is $x_1 = vt$. The other pulse starts from the right end, at $x = L$, where L is the length of the wire, at time $t = 30$ ms. If this time is denoted by t_0 , then the coordinate of this wave at time t is $x_2 = L - v(t - t_0)$. They meet when $x_1 = x_2$, or, what is the same, when $vt = L - v(t - t_0)$. We solve for the time they meet: $t = (L + vt_0)/2v$ and the coordinate of the meeting point is $x = vt = (L + vt_0)/2$. Now, we calculate the wave speed:

$$v = \sqrt{\frac{\tau L}{m}} = \sqrt{\frac{(250 \text{ N})(10.0 \text{ m})}{0.100 \text{ kg}}} = 158 \text{ m/s}.$$

Here τ is the tension in the wire and L/m is the linear mass density of the wire. The coordinate of the meeting point is

$$x = \frac{10.0 \text{ m} + (158 \text{ m/s})(30.0 \times 10^{-3} \text{ s})}{2} = 7.37 \text{ m}.$$

This is the distance from the left end of the wire. The distance from the right end is $L - x = (10.0 \text{ m} - 7.37 \text{ m}) = 2.63 \text{ m}$.

33. (a) The amplitude of the second wave is $y_m = 9.00 \text{ mm}$, as stated in the problem.

(b) The figure indicates that $\lambda = 40 \text{ cm} = 0.40 \text{ m}$, which implies that the angular wave number is $k = 2\pi/0.40 = 16 \text{ rad/m}$.

(c) The figure (along with information in the problem) indicates that the speed of each wave is $v = dx/t = (56.0 \text{ cm})/(8.0 \text{ ms}) = 70 \text{ m/s}$. This, in turn, implies that the angular frequency is

$$\omega = kv = 1100 \text{ rad/s} = 1.1 \times 10^3 \text{ rad/s}.$$

(d) The figure depicts two traveling waves (both going in the $-x$ direction) of equal amplitude y_m . The amplitude of their resultant wave, as shown in the figure, is $y'_m = 4.00 \text{ mm}$. Equation 16-52 applies:

$$y'_m = 2y_m \cos\left(\frac{1}{2}\phi_2\right) \Rightarrow \phi_2 = 2 \cos^{-1}(2.00/9.00) = 2.69 \text{ rad}.$$

(e) In making the plus-or-minus sign choice in $y = y_m \sin(kx \pm \omega t + \phi)$, we recall the discussion in section 16-5, where it was shown that sinusoidal waves traveling in the $-x$ direction are of the form $y = y_m \sin(kx + \omega t + \phi)$. Here, ϕ should be thought of as the phase *difference* between the two waves (that is, $\phi_1 = 0$ for wave 1 and $\phi_2 = 2.69 \text{ rad}$ for wave 2).

In summary, the waves have the forms (with SI units understood):

$$y_1 = (0.00900)\sin(16x + 1100t) \quad \text{and} \quad y_2 = (0.00900)\sin(16x + 1100t + 2.7).$$

41. (a) The wave speed is given by $v = \sqrt{\tau/\mu}$, where τ is the tension in the string and μ is the linear mass density of the string. Since the mass density is the mass per unit length, $\mu = M/L$, where M is the mass of the string and L is its length. Thus

$$v = \sqrt{\frac{\tau L}{M}} = \sqrt{\frac{(96.0 \text{ N})(8.40 \text{ m})}{0.120 \text{ kg}}} = 82.0 \text{ m/s}.$$

(b) The longest possible wavelength λ for a standing wave is related to the length of the string by $L = \lambda/2$, so $\lambda = 2L = 2(8.40 \text{ m}) = 16.8 \text{ m}$.

(c) The frequency is $f = v/\lambda = (82.0 \text{ m/s})/(16.8 \text{ m}) = 4.88 \text{ Hz}$.

49. (a) Equation 16-26 gives the speed of the wave:

$$v = \sqrt{\frac{\tau}{\mu}} = \sqrt{\frac{150 \text{ N}}{7.20 \times 10^{-3} \text{ kg/m}}} = 144.34 \text{ m/s} \approx 1.44 \times 10^2 \text{ m/s}.$$

(b) From the figure, we find the wavelength of the standing wave to be

$$\lambda = (2/3)(90.0 \text{ cm}) = 60.0 \text{ cm}.$$

(c) The frequency is

$$f = \frac{v}{\lambda} = \frac{1.44 \times 10^2 \text{ m/s}}{0.600 \text{ m}} = 241 \text{ Hz.}$$