Chapter 16: Waves - I
Questions and Example Problems

\[ y(x,t) = y_m \sin(kx - \omega t) \quad \omega = \frac{2\pi}{T} = 2\pi f \quad k = \frac{2\pi}{\lambda} \quad v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f \]

\[ y_n(x,t) = [2y_m \cos(\frac{\pi}{2} \phi)] \sin(kx - \omega t + \frac{\phi}{2}) \quad \phi = 2\pi \frac{\Delta L}{\lambda} = \begin{cases} 2\pi m, & m = 0,1,2,3,... \text{ (constructive)} \\ 2\pi (m + \frac{1}{2}), & m = 0,1,2,3,... \text{ (destructive)} \end{cases} \]

\[ y_{\text{Standing}}(x,t) = [2y_m \sin kx] \cos kx \quad f_n = \frac{v}{\lambda_n} = n \left( \frac{v}{2L} \right) \quad n = 1,2,3,... \quad v = \sqrt{\frac{F}{\mu}} \quad \mu = \frac{m}{L} \]

Example 16.1

- A special device can transmit sound out of phase from a noisy jackhammer to its operator using earphones. Over the noise of the jackhammer, the operator can easily hear your voice while you are unable to hear this. Explain.
- The four strings on a violin have different thicknesses, but are all under approximately the same tension. Do waves travel faster on the thick strings or the thin strings? Why? How does the fundamental vibration frequency compare for the thick versus the thin strings?
- A long rope with mass \( m \) is suspended from the ceiling and hangs vertically. A wave pulse is produced at the lower end of the rope and the pulse travels up the rope. Does the speed of the wave pulse change as it moves up the rope, and if so, does it increase or decrease?
- Children make toy telephones by sticking each end of a long string through a hole in the bottom of a paper cup and knotting it so it will not pull out. When the string is pulled taut, sound can be transmitted from one cup to the other. How does this work? Why is the transmitted sound louder than the sound traveling through air for the same distance?

Example 16.2

A stretch string has a mass per unit length of 5.0 g/cm and a tension of 10N. A sinusoidal wave on this string has amplitude of 0.12 mm and a frequency of 100 Hz and is traveling in the negative direction of \( x \). Write an equation for this wave.

Example 16.3

Two sound sources oscillate in phase and emit waves of the same amplitude. At a point 5.0 m from one source and 5.17 m from the other, find the resultant amplitude due to interference for (a) 1000 Hz, (b) 2000 Hz, and (c) 500 Hz.
Example 16.4
Two waves are described by $y_1 = 0.30 \sin[\pi(5x-200)t]$ and $y_2 = 0.30 \sin[\pi(5x-200)t+\pi/3]$, where $y_1$, $y_2$, and $x$ are in meters and $t$ is in seconds. When these two waves are combined, a traveling wave is produced. What are (a) the amplitude, (b) the wave speed, and (c) the wavelength of that traveling wave?

Example 16.5
A 1.50 m wire has a mass of 8.7 g and is under tension of 120 N. The wire is held rigidly at both ends and set into oscillation. Calculate (a) the speed of waves in the wire, (b) the wavelengths of the waves that produce three- and seven-loop standing waves on the string, and (c) the frequencies of the waves that produce three- and seven-loop standing waves.

Example 16.6
A rope, under a tension of 200 N and fixed at both ends, oscillates in a second-harmonic standing wave pattern. The displacement of the rope is given by

$$y = (0.10 \text{ m}) \sin(\pi x / 2) \cdot \sin(12\pi t)$$

where $x = 0$ at one end of the rope, $x$ is in meters, and $t$ is in seconds. What are (a) the length of the rope, (b) the speed of the waves on the rope, and (c) the mass of the rope? (d) If the rope oscillates in a third-harmonic standing wave pattern, what will be the period of oscillation?