Chapter 18.

1. A tuning fork generates sound waves with a frequency of 246 Hz. The waves travel in opposite directions along a hallway, are reflected by end walls, and return. The hallway is 47.0 m long and the tuning fork is located 14.0 m from one end. What is the phase difference between the reflected waves when they meet at the tuning fork? The speed of sound in air is 343 m/s.

   Ans:

   Waves reflecting from the near end travel 28.0 m (14.0 m down and 14.0 m back), while waves reflecting from the far end travel 66.0 m. The path difference for the two waves is:

   $$\Delta r = 66.0 \text{ m} - 28.0 \text{ m} = 38.0 \text{ m}$$

   Since $\lambda = \dfrac{\upsilon}{f}$

   Then

   $$\frac{\Delta r}{\lambda} = \frac{(\Delta r) f}{\upsilon} = \frac{(38.0\,\text{m})(246\,\text{Hz})}{343 \text{ m/s}} = 27.254$$

   or $\Delta r = 27.254\lambda$

   The phase difference between the two reflected waves is then

   $$\phi = (0.254)(1\,\text{cycle}) = (0.254)(2\pi\,\text{rad}) = 1.594\,\text{rad} = \boxed{91.3°}$$

2. Two sinusoidal waves traveling in opposite directions interfere to produce a standing wave with the wave function $y = 1.50 \sin(0.400x) \cos(200t)$ where x and y are in meters and t is in seconds. Determine (a) the wavelength, (b) the frequency, and (c) the speed of the interfering waves.

   Ans:

   $y = (1.50 \text{ m}) \sin(0.400x) \cos(200t) = 2A_0 \sin kx \cos \omega t$

   Compare corresponding parts:

   (a)

   $$k = \frac{2\pi}{\lambda} = 0.400\,\text{rad/m}$$

   $$\lambda = \frac{2\pi}{0.400\,\text{rad/m}} = \boxed{15.7\,\text{m}}$$

   (b) $\omega = 2\pi f$ so $f = \dfrac{\omega}{2\pi} = \dfrac{200\,\text{rad/s}}{2\pi\,\text{rad}} = \boxed{31.8\,\text{Hz}}$

   (c) The speed of waves in the medium is

   $$\upsilon = \lambda f = \frac{\lambda}{2\pi} 2\pi k f = \frac{\omega}{k} = \frac{200 \text{ rad/s}}{0.400 \text{ rad/m}} = \boxed{500\,\text{m/s}}$$

3. A string with a mass $m = 8.00$ g and a length $L = 5.00$ m has one end attached to a wall; the other

end is draped over a small, fixed pulley a distance $d = 4.00$ m from the wall and attached to a hanging object with a mass $M = 4.00$ kg as in Figure P18.21. If the horizontal part of the string is plucked, what is the fundamental frequency of its vibration?

Ans:

Using L_υ for the vibrating portion of the string of total length L,

$$f = \frac{\upsilon}{2L_\upsilon} = \frac{1}{2L_\upsilon}\sqrt{\frac{T}{\mu}} = \frac{1}{2L_\upsilon}\sqrt{\frac{MgL}{m}}$$

$$= \frac{1}{2(4.00\,\mathrm{m})}\sqrt{\frac{(4.00\,\mathrm{kg})(9.80\,\mathrm{m/s^2})(5.00\,\mathrm{m})}{0.008\,00\,\mathrm{kg}}} = \boxed{19.6\,\mathrm{Hz}}$$

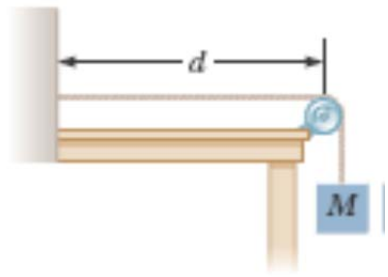


Figure P18.21

4. Calculate the length of a pipe that has a fundamental frequency of 240 Hz assuming the pipe is (a) closed at one end and (b) open at both ends.

Ans:

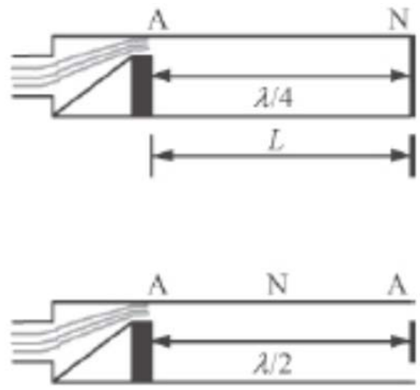
(a) For the fundamental mode in a closed pipe, λ=4L, as in the diagram.

But $\upsilon = f\lambda$, therefore $L = \dfrac{\upsilon}{4f}$.

So, $L = \dfrac{343\,\mathrm{m/s}}{4\left(240\,\mathrm{s^{-1}}\right)} = \boxed{0.357\,\mathrm{m}}$

(b) For an open pipe, λ=2L, as in the diagram.

So, $L = \dfrac{\upsilon}{2f} = \dfrac{343\,\mathrm{m/s}}{2\left(240\,\mathrm{s^{-1}}\right)} = \boxed{0.715\,\mathrm{m}}$



ANS. FIG. P18.39

5. A glass tube (open at both ends) of length L is positioned near an audio speaker of frequency $f = 680$ Hz. For what values of L will the tube resonate with the speaker?

Ans:

$$\frac{\lambda}{2} = d_{\mathrm{AA}} = \frac{L}{n} \quad \text{or} \quad L = \frac{n\lambda}{2} \qquad \text{for } n = 1, 2, 3, \ldots$$

$$\text{Since } \lambda = \frac{\upsilon}{f}, L = n\left(\frac{\upsilon}{2f}\right) \qquad \text{for } n = 1, 2, 3, \ldots$$

With υ=343 m/s and f=680 Hz,

$$L = n\left(\frac{343\,\mathrm{m/s}}{2(680\,\mathrm{Hz})}\right) = n(0.252\,\mathrm{m}) \quad \text{for } n = 1, 2, 3, \ldots$$

Possible lengths for resonance are: $L = \boxed{0.252\text{ m}, 0.504\text{ m}, 0.757\text{ m}, \ldots, n(0.252)\text{ m}}$