5. **REASONING AND SOLUTION** From Equation 16.1, we have \( \lambda = \frac{v}{f} \). But \( v = \frac{x}{t} \), so we find

\[
\lambda = \frac{v}{f} = \frac{x}{tt} = \frac{2.5 \text{ m}}{(1.7 \text{ s})(3.0 \text{ Hz})} = 0.49 \text{ m}
\]

8. **REASONING AND SOLUTION** The period of the waves is \( T = 7.0 \text{ s}/3 = 2.3 \text{ s} \). The frequency is then \( f = 1/T = 0.43 \text{ Hz} \). The wavelength is \( \lambda = 4.0 \text{ m} \). The speed is

\[
v = \lambda f = (4.0 \text{ m})(0.43 \text{ Hz}) = 1.7 \text{ m/s}
\]

12. **REASONING AND SOLUTION** The speed of the wave is

\[
v = \sqrt{\frac{F}{m/L}} = f\lambda \quad (16.2)
\]

Solving for the mass \( m \) of the string gives

\[
m = \frac{FL}{f^2 \lambda^2} = \frac{(2.3 \text{ N})(0.75 \text{ m})}{(150 \text{ Hz})^2 (0.40 \text{ m})^2} = 4.8 \times 10^{-4} \text{ kg}
\]

15. **WWW** **REASONING** According to Equation 16.2, the linear density of the string is given by \( (m/L) = F/v^2 \), where the speed \( v \) of waves on the middle C string is given by Equation 16.1, \( v = \lambda f = \lambda / T \).

**SOLUTION** Combining Equations 16.2 and 16.1 and using the given data, we obtain

\[
m / L = \frac{F}{v^2} = \frac{FT^2}{\lambda^2} = \frac{(944 \text{ N})(3.82 \times 10^{-3} \text{ s})^2}{(1.26 \text{ m})^2} = 8.68 \times 10^{-3} \text{ kg/m}
\]

31. **REASONING AND SOLUTION**

\[
\lambda = v/f = (343 \text{ m/s})/(4185.6 \text{ Hz}) = 8.19 \times 10^{-2} \text{ m} \quad (16.1)
\]
49. **REASONING AND SOLUTION** Since the sound radiates uniformly in all directions, at a distance \( r \) from the source, the energy of the sound wave is distributed over the area of a sphere of radius \( r \). Therefore, according to Equation 16.9 \([ I = P/(4\pi r^2) ]\) with \( r = 3.8 \, \text{m} \), the power radiated from the source is

\[
P = 4\pi I r^2 = 4\pi (3.6 \times 10^{-2} \, \text{W/m}^2)(3.8 \, \text{m})^2 = 6.5 \, \text{W}
\]

62. **REASONING AND SOLUTION**

a. \( \beta = (10 \, \text{dB}) \log \left( \frac{P_A}{P_B} \right) = (10 \, \text{dB}) \log \left( \frac{(250 \, \text{W})}{(45 \, \text{W})} \right) = 7.4 \, \text{dB} \)

b. \( \text{No} \), A will not be twice as loud as B since it requires an increase of 10 dB to double the loudness.

63. **REASONING** According to Equation 16.10, the sound intensity level \( \beta \) in decibels (dB) is related to the sound intensity \( I \) according to \( \beta = (10 \, \text{dB}) \log \left( \frac{I}{I_0} \right) \), where the quantity \( I_0 \) is the reference intensity. Since the sound is emitted uniformly in all directions, the intensity, or power per unit area, is given by \( I = P/(4\pi r^2) \). Thus, the sound intensity at position 1 can be written as \( I_1 = P/(4\pi r_1^2) \), while the sound intensity at position 2 can be written as \( I_2 = P/(4\pi r_2^2) \). Therefore, the difference in the sound intensity level \( \beta_{21} \) between the two positions is

\[
\beta_{21} = \beta_2 - \beta_1 = (10 \, \text{dB}) \log \left( \frac{I_2}{I_0} \right) - (10 \, \text{dB}) \log \left( \frac{I_1}{I_0} \right) = (10 \, \text{dB}) \log \left( \frac{I_2 / I_0}{I_1 / I_0} \right) = (10 \, \text{dB}) \log \left( \frac{I_2}{I_1} \right)
\]

\[
\beta_{21} = (10 \, \text{dB}) \log \left[ \frac{P/(4\pi r_2^2)}{P/(4\pi r_1^2)} \right] = (10 \, \text{dB}) \log \left( \frac{r_1^2}{r_2^2} \right) = (10 \, \text{dB}) \log \left( \frac{r_1}{r_2} \right)^2
\]

\[
= (20 \, \text{dB}) \log \left( \frac{r_1}{r_2} \right) = (20 \, \text{dB}) \log \left( \frac{r_1}{2r_1} \right) = (20 \, \text{dB}) \log (1/2) = -6.0 \, \text{dB}
\]

The negative sign indicates that the sound intensity level decreases.
The intensity level at each point is given by

$$I = \frac{P}{4\pi r^2}$$

Therefore,

$$\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$$

Since the two intensity levels differ by 2.00 dB, the intensity ratio is

$$\frac{I_1}{I_2} = 10^{0.200} = 1.58$$

Thus,

$$\left(\frac{r_2}{r_1}\right)^2 = 1.58$$

We also know that \(r_2 - r_1 = 1.00\) m. We can then solve the two equations simultaneously by substituting, i.e., \(r_2 = r_1\sqrt{1.58}\) gives

$$r_1\sqrt{1.58} - r_1 = 1.00\) m

so that

$$r_1 = \frac{(1.00\) m}/(\sqrt{1.58} - 1) = 3.9\) m$$

and

$$r_2 = 1.00\) m + r_1 = 4.9\) m$$

In this situation, the observer is moving toward a stationary source of waves. The frequency \(f_0\) detected by the moving observer is related to the frequency \(f_s\) emitted by the source by

$$f_0 = f_s \left(1 + \frac{v_o}{v}\right) \quad (16.13)$$

where \(v_o\) is the speed of the observer and \(v\) is the speed of the waves. The frequency \(f_s\) is related to the speed \(v\) of the waves and their wavelength \(\lambda\) by Equation 16.1, \(f_s = \nu/\lambda\). Substituting this value for \(f_s\) into Equation 16.13 gives

$$f_0 = \left(\frac{\nu}{\lambda}\right) \left(1 + \frac{v_o}{v}\right)$$

The frequency of the waves, as detected by the moving observer, is

$$f_0 = \left(\frac{\nu}{\lambda}\right) \left(1 + \frac{v_o}{v}\right) = \left(\frac{6.70\) m/s}{13.4\) m}\right) \left(1 + \frac{4.20\) m/s}{6.70\) m/s}\right) = 0.813\) Hz
49. **REASONING AND SOLUTION** Since the sound radiates uniformly in all directions, at a distance \( r \) from the source, the energy of the sound wave is distributed over the area of a sphere of radius \( r \). Therefore, according to Equation 16.9 \([I = P/(4\pi r^2)]\) with \( r = 3.8 \text{ m} \), the power radiated from the source is

\[
P = 4\pi r^2 = 4\pi (3.6 \times 10^{-2} \text{ W/m}^2)(3.8 \text{ m})^2 = 6.5 \text{ W}
\]

62. **REASONING AND SOLUTION**

a. \( \beta = (10 \text{ dB}) \log \left( \frac{P_A}{P_B} \right) = (10 \text{ dB}) \log \left( \frac{(250 \text{ W})}{(45 \text{ W})} \right) = 7.4 \text{ dB} \)

b. **No**, A will not be twice as loud as B since it requires an increase of 10 dB to double the loudness.

63. **REASONING** According to Equation 16.10, the sound intensity level \( \beta \) in decibels (dB) is related to the sound intensity \( I \) according to \( \beta = (10 \text{ dB}) \log \left( \frac{I}{I_0} \right) \), where the quantity \( I_0 \) is the reference intensity. Since the sound is emitted uniformly in all directions, the intensity, or power per unit area, is given by \( I = P/(4\pi r^2) \). Thus, the sound intensity at position 1 can be written as \( I_1 = P/(4\pi r_1^2) \), while the sound intensity at position 2 can be written as \( I_2 = P/(4\pi r_2^2) \). Therefore, the difference in the sound intensity level \( \beta_{21} \) between the two positions is

\[
\beta_{21} = \beta_2 - \beta_1 = (10 \text{ dB}) \log \left( \frac{I_2}{I_0} \right) - (10 \text{ dB}) \log \left( \frac{I_1}{I_0} \right) = (10 \text{ dB}) \log \left( \frac{I_2}{I_1} \right) = (10 \text{ dB}) \log \left( \frac{I_2}{I_1} \right)
\]

\[
\beta_{21} = (10 \text{ dB}) \log \left[ \frac{P/(4\pi r_2^2)}{P/(4\pi r_1^2)} \right] = (10 \text{ dB}) \log \left( \frac{r_1^2}{r_2^2} \right) = (10 \text{ dB}) \log \left( \frac{r_1}{r_2} \right)^2
\]

\[
= (20 \text{ dB}) \log \left( \frac{r_1}{r_2} \right) = (20 \text{ dB}) \log \left( \frac{r_1}{2r_1} \right) = (20 \text{ dB}) \log (1/2) = -6.0 \text{ dB}
\]

The negative sign indicates that the sound intensity level decreases.
68. **REASONING AND SOLUTION** The intensity level at each point is given by

\[ I = \frac{P}{4\pi r^2} \]

Therefore,

\[ \frac{I_1}{I_2} = \left( \frac{r_2}{r_1} \right)^2 \]

Since the two intensity levels differ by 2.00 dB, the intensity ratio is

\[ \frac{I_1}{I_2} = 10^{0.200} = 1.58 \]

Thus,

\[ \left( \frac{r_2}{r_1} \right)^2 = 1.58 \]

We also know that \( r_2 - r_1 = 1.00 \) m. We can then solve the two equations simultaneously by substituting, i.e., \( r_2 = r_1 \sqrt{1.58} \) gives

\( r_1 \sqrt{1.58} - r_1 = 1.00 \) m

so that

\[ r_1 = (1.00 \text{ m}) / (\sqrt{1.58} - 1) = 3.9 \text{ m} \]

and

\[ r_2 = 1.00 \text{ m} + r_1 = 4.9 \text{ m} \]

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70. **REASONING** In this situation, the observer is moving toward a stationary source of waves. The frequency \( f_o \) detected by the moving observer is related to the frequency \( f_s \) emitted by the source by

\[ f_o = f_s \left( 1 + \frac{v_o}{v} \right) \tag{16.13} \]

where \( v_o \) is the speed of the observer and \( v \) is the speed of the waves. The frequency \( f_s \) is related to the speed \( v \) of the waves and their wavelength \( \lambda \) by Equation 16.1, \( f_s = v/\lambda \). Substituting this value for \( f_s \) into Equation 16.13 gives

\[ f_o = \left( \frac{v}{\lambda} \right) \left( 1 + \frac{v_o}{v} \right) \]

**SOLUTION** The frequency of the waves, as detected by the moving observer, is

\[ f_o = \left( \frac{v}{\lambda} \right) \left( 1 + \frac{v_o}{v} \right) = \left( \frac{6.70 \text{ m/s}}{13.4 \text{ m}} \right) \left( 1 + \frac{4.20 \text{ m/s}}{6.70 \text{ m/s}} \right) = 0.813 \text{ Hz} \]