7. **Reasoning** The geometry of the positions of the loudspeakers and the listener is shown in the following drawing.

The listener at C will hear either a loud sound or no sound, depending upon whether the interference occurring at C is constructive or destructive. If the listener hears no sound, destructive interference occurs, so

\[ d_2 - d_1 = \frac{n\lambda}{2} \quad n = 1, 3, 5, ... \]  

(1)

**Solution** Since \( v = \lambda f \), according to Equation 16.1, the wavelength of the tone is

\[ \lambda = \frac{v}{f} = \frac{343 \text{ m/s}}{68.6 \text{ Hz}} = 5.00 \text{ m} \]

Speaker B will be closest to Speaker A when \( n = 1 \) in Equation (1) above, so

\[ d_2 = \frac{n\lambda}{2} + d_1 = \frac{5.00 \text{ m}}{2} + 1.00 \text{ m} = 3.50 \text{ m} \]

From the figure above we have that,

\[ x_1 = (1.00 \text{ m}) \cos 60.0^\circ = 0.500 \text{ m} \]

\[ y = (1.00 \text{ m}) \sin 60.0^\circ = 0.866 \text{ m} \]

Then
Therefore, the closest that speaker A can be to speaker B so that the listener hears no sound is \( x_1 + x_2 = 0.500 \text{ m} + 3.39 \text{ m} = 3.89 \text{ m} \).

33. **SSM**  **WWW**  **REASONING**  The natural frequencies of the cord are, according to Equation 17.3, \( f_n = \frac{nv}{(2\, L)} \), where \( n = 1, 2, 3, \ldots \). The speed \( v \) of the waves on the cord is, according to Equation 16.2, \( v = \sqrt{\frac{F}{(m/L)}} \), where \( F \) is the tension in the cord. Combining these two expressions, we have

\[
\frac{f_n \, v}{2\, L} = \frac{n}{2\, L} \sqrt{\frac{F}{m/L}} \quad \text{or} \quad \left( \frac{f_n \, 2\, L}{n} \right)^2 = \frac{F}{m/L}
\]

Applying Newton's second law of motion, \( \Sigma F = ma \), to the forces that act on the block and are parallel to the incline gives

\[
F - Mg \sin \theta = Ma = 0 \quad \text{or} \quad F = Mg \sin \theta
\]

where \( Mg \sin \theta \) is the component of the block's weight that is parallel to the incline. Substituting this value for the tension into the equation above gives

\[
\left( \frac{f_n \, 2\, L}{n} \right)^2 = \frac{Mg \sin \theta}{m/L}
\]

This expression can be solved for the angle \( \theta \) and evaluated at the various harmonics. The answer can be chosen from the resulting choices.

**SOLUTION**  Solving this result for \( \sin \theta \) shows that

\[
\sin \theta = \frac{(m/L)}{Mg} \left( \frac{f_n \, 2\, L}{n} \right)^2 = \frac{1.20 \times 10^{-2} \text{ kg/m}}{(15.0 \text{ kg})(9.80 \text{ m/s}^2)} \left[ \frac{(165 \text{ Hz})2(0.600 \text{ m})}{n} \right]^2 = \frac{3.20}{n^2}
\]

Thus, we have

\[
\theta = \sin^{-1} \left( \frac{3.20}{n^2} \right)
\]

Evaluating this for the harmonics corresponding to the range of \( n \) from \( n = 2 \) to \( n = 4 \), we have
43. **REASONING** According to Equation 11.4, the absolute pressure at the bottom of the mercury is $P = P_{\text{atm}} + \rho gh$, where the height $h$ of the mercury column is the original length $L_0$ of the air column minus the shortened length $L$. Hence,

$$P = P_{\text{atm}} + \rho g (L_0 - L)$$

**SOLUTION** From Equation 17.5, the fundamental ($n = 1$) frequency $f_1$ of the shortened tube is $f_1 = 1(v/4L)$, where $L$ is the length of the air column in the tube. Likewise, the frequency $f_3$ of the third ($n = 3$) harmonic in the original tube is $f_3 = 3(v/4L_0)$, where $L_0$ is the length of the air column in the original tube. Since $f_1 = f_3$, we have that

$$1 \left( \frac{v}{4L} \right) = 3 \left( \frac{v}{4L_0} \right) \quad \text{or} \quad L = \frac{1}{3} L_0$$

The pressure at the bottom of the mercury is

$$P = P_{\text{atm}} + \rho g \left( \frac{2}{3} L_0 \right)$$

$$= 1.01 \times 10^5 \text{ Pa} + (13 \ 600 \text{ kg/m}^3)(9.80 \text{ m/s}^2)\left( \frac{2}{3} \times 0.75 \text{ m} \right) = 1.68 \times 10^5 \text{ Pa}$$

55. **REASONING** The beat frequency produced when the piano and the other instrument sound the note (three octaves higher than middle C) is $f_{\text{beat}} = f - f_0$, where $f$ is the frequency of the piano and $f_0$ is the frequency of the other instrument ($f_0 = 2093$ Hz). We can find $f$ by considering the temperature effects and the mechanical effects that occur when the temperature drops from 25.0 °C to 20.0 °C.

**SOLUTION** The fundamental frequency $f_0$ of the wire at 25.0 °C is related to the tension $F_0$ in the wire by
Chapter 17 Problems

\[ f_0 = \frac{v}{2L_0} = \sqrt{\frac{F_0 / (m/L)}{2L_0}} \]  
where Equations 17.3 and 16.2 have been combined.

The amount \( \Delta L \) by which the piano wire attempts to contract is (see Equation 12.2) \( \Delta L = \alpha L_0 \Delta T \), where \( \alpha \) is the coefficient of linear expansion of the wire, \( L_0 \) is its length at 25.0 °C, and \( \Delta T \) is the amount by which the temperature drops. Since the wire is prevented from contracting, there must be a stretching force exerted at each end of the wire. According to Equation 10.17, the magnitude of this force is

\[ \Delta F = Y \left( \frac{\Delta L}{L_0} \right) A \]

where \( Y \) is the Young's modulus of the wire, and \( A \) is its cross-sectional area. Combining this relation with Equation 12.2, we have

\[ \Delta F = Y \left( \frac{\alpha L_0 \Delta T}{L_0} \right) A = \alpha(\Delta T)YA \]

Thus, the frequency \( f \) at the lower temperature is

\[ f = \frac{v}{2L_0} = \sqrt{\left( \frac{F_0 + \Delta F}{m/L} \right) / \left( 2L_0 \right)} = \sqrt{\left[ \frac{F_0 + \alpha(\Delta T)YA}{m/L} \right] / \left( 2L_0 \right)} \]

(2)

Using Equations (1) and (2), we find that the frequency \( f \) is

\[ f = f_0 \sqrt{\left[ \frac{F_0 + \alpha(\Delta T)YA}{m/L} \right] / \left( F_0 / (m/L) \right)} = f_0 \sqrt{\frac{F_0 + \alpha(\Delta T)YA}{F_0}} \]

\[ f = \left( 2093 \text{ Hz} \right) \sqrt{\frac{818.0 \text{ N} + (12 \times 10^{-6} / \text{°C})(5.0 \text{ °C})(2.0 \times 10^{11} \text{ N/m}^2)(7.85 \times 10^{-7} \text{ m}^2)}{818.0 \text{ N}}} \]

\[ = 2105 \text{ Hz} \]

Therefore, the beat frequency is \( 2105 \text{ Hz} - 2093 \text{ Hz} = 12 \text{ Hz} \).