PHY 2130 Homework solutions
Assignment 13

14.4 At $T = 27°\text{C} = 300\ \text{K}$, the speed of sound in air is

$$v = (331\ \text{m/s})\sqrt{\frac{T}{273\ \text{K}}} = (331\ \text{m/s})\sqrt{\frac{300\ \text{K}}{273\ \text{K}}} = 347\ \text{m/s}$$

The wavelength of the 20 Hz sound is $\lambda = \frac{v}{f} = \frac{347\ \text{m/s}}{20\ \text{Hz}} = 17\ \text{m}$, and that of the 20 000 Hz is $\lambda = \frac{347\ \text{m/s}}{20\,000\ \text{Hz}} = 1.7 \times 10^{-2}\ \text{m} = 1.7\ \text{cm}$. Thus, range of wavelengths of audible sounds at 27°C is $\boxed{1.7\ \text{cm to } 17\ \text{m}}$.

14.25 With the train *approaching* at speed v_t, the observed frequency is

$$442\ \text{Hz} = f\left(\frac{345\ \text{m/s} + 0}{345\ \text{m/s} - v_t}\right) = f\left(\frac{345\ \text{m/s}}{345\ \text{m/s} - v_t}\right) \qquad (1)$$

As the train *recedes*, the observed frequency is

$$441\ \text{Hz} = f\left[\frac{345\ \text{m/s} + 0}{345\ \text{m/s} - (-v_t)}\right] = f\left(\frac{345\ \text{m/s}}{345\ \text{m/s} + v_t}\right) \qquad (2)$$

Dividing equation (1) by (2) gives $\frac{442}{441} = \frac{345\ \text{m/s} + v_t}{345\ \text{m/s} - v_t}$,

and solving for the speed of the train yields $v_t = \boxed{0.391\ \text{m/s}}$

14.36 The mass per unit length of the wire is

$$\mu = \frac{m}{L} = \frac{0.300 \times 10^{-3}\ \text{kg}}{70.0 \times 10^{-2}\ \text{m}} = 4.29 \times 10^{-4}\ \text{kg/m}\ ,$$

and the speed of transverse waves is

$$v = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{600\ \text{N}}{4.29 \times 10^{-4}\ \text{kg/m}}} = 1.18 \times 10^{3}\ \text{m/s}$$

The fundamental or first harmonic of the wire has a wavelength of $\lambda_1 = 2L = 1.40\ \text{m}$, and frequency $f_1 = \dfrac{v}{\lambda_1} = \dfrac{1.18 \times 10^{3}\ \text{m/s}}{1.40\ \text{m}} = \boxed{845\ \text{Hz}}$.

The frequency of the second harmonic is $f_2 = 2f_1 = \boxed{1.69 \times 10^{3}\ \text{Hz}}$ and that of the third harmonic is $f_3 = 3f_1 = \boxed{2.54 \times 10^{3}\ \text{Hz}}$.

14.45 Hearing would be best at the fundamental resonance, so $\lambda = 4L = 4(2.8\ \text{cm})$

and $$f = \frac{v}{\lambda} = \frac{340\ \text{m/s}}{4(2.8\ \text{cm})}\left(\frac{100\ \text{cm}}{1\ \text{m}}\right) = 3.0 \times 10^{3}\ \text{Hz} = \boxed{3.0\ \text{kHz}}$$

14.47 (a) The speed of sound is $331\ \text{m/s}$ at 0 °C, so the fundamental wavelength of the pipe open at both ends is

$$\lambda_1 = 2L = \frac{v}{f_1}\ \text{ giving }\ L = \frac{v}{2f_1} = \frac{331\ \text{m/s}}{2(300\ \text{Hz})} = \boxed{0.552\ \text{m}}$$

(b) At $T = 30\ °\text{C} = 303\ \text{K}$, $v = (331\ \text{m/s})\sqrt{\dfrac{T}{273\ \text{K}}} = (331\ \text{m/s})\sqrt{\dfrac{303\ \text{K}}{273\ \text{K}}} = 349\ \text{m/s}$

and $$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L} = \frac{349\ \text{m/s}}{2(0.552\ \text{m})} = \boxed{316\ \text{Hz}}$$