Homework 4

Chapter 17

P17.39 (a) The Doppler-shifted frequency is found from

$$f' = \frac{f\left(v+v_o\right)}{\left(v-v_s\right)}$$

$$= \left(2\,500\text{ Hz}\right)\frac{(343+25.0)}{(343-40.0)} = \boxed{3.04\text{ kHz}}$$

(b) After the police car passes,

$$f' = \left(2\,500\text{ Hz}\right)\left(\frac{343+(-25.0)}{343-(-40.0)}\right) = \boxed{2.08\text{ kHz}}$$

(c) While the police car overtakes the driver,

$$f' = \left(2\,500\text{ Hz}\right)\left(\frac{343+(-25.0)}{343-40.0}\right) = \boxed{2.62\text{ kHz}}$$

After the police car passes,

$$f' = \left(2\,500\text{ Hz}\right)\left(\frac{343+25.0}{343-(-40.0)}\right) = \boxed{2.40\text{ kHz}}$$

P17.47 (a) We find the shock angle from

$$\theta = \sin\left(\frac{v}{v_S}\right)^{-1} = \sin\left(\frac{1}{3.00}\right)^{-1} = 19.5°$$

from $\tan\theta = \frac{h}{x}$,

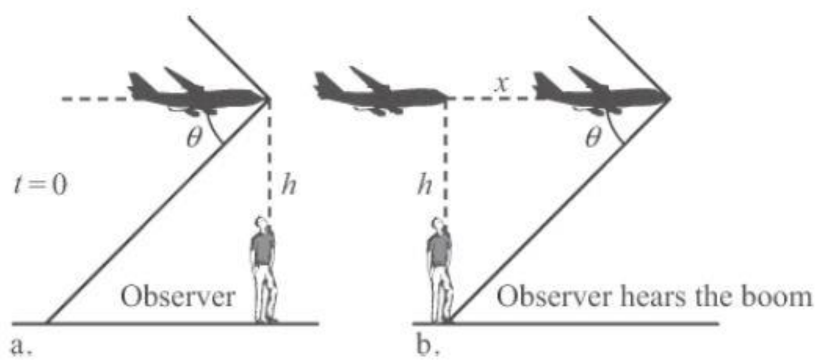
$$x = \frac{h}{\tan\theta} = \frac{20\,000\text{ m}}{\tan 19.5°} = 5.66\times10^{4}\text{ m} = 56.6\text{ km}$$

It takes the plane

$$t = \frac{x}{v_S} = \frac{5.66\times10^{4}\text{ m}}{3.00(335\text{ m/s})} = \boxed{56.3\text{ s}}$$

to travel this distance.

(b) From part (a), $x = \boxed{56.6\text{ km}}$



ANS. FIG. P17.47

P17.63 (a) If the velocity of the insect is v_x,

$$40.4 \text{ kHz} = (40.0 \text{ kHz})\frac{(343 \text{ m/s} + 5.00 \text{ m/s})(343 \text{ m/s} - v_x)}{(343 \text{ m/s} - 5.00 \text{ m/s})(343 \text{ m/s} + v_x)}$$

Solving, $v_x = \boxed{3.29 \text{ m/s}}$.

(b) Therefore, $\boxed{\text{the bat is gaining on its prey at } 1.71 \text{ m/s}}$.

P17.64 When the observer is moving in front of and in the same direction as the source, $f' = f\frac{v - v_O}{v - v_S}$, where v_O and v_S are measured relative to the medium in which the sound is propagated. In this case the ocean current is opposite the direction of travel of the ships, and

$$v_O = 45.0 \text{ km/h} - (-10.0 \text{ km/h}) = 55.0 \text{ km/h} = 15.3 \text{ m/s}, \text{ and}$$
$$v_S = 64.0 \text{ km/h} - (-10.0 \text{ km/h}) = 74.0 \text{ km/h} = 20.55 \text{ m/s}$$

Therefore,

$$f' = (1\ 200.0 \text{ Hz})\frac{(1\ 533 \text{ m/s}) - (15.3 \text{ m/s})}{(1\ 533 \text{ m/s}) - (20.55 \text{ m/s})} = \boxed{1\ 204.2 \text{ Hz}}$$

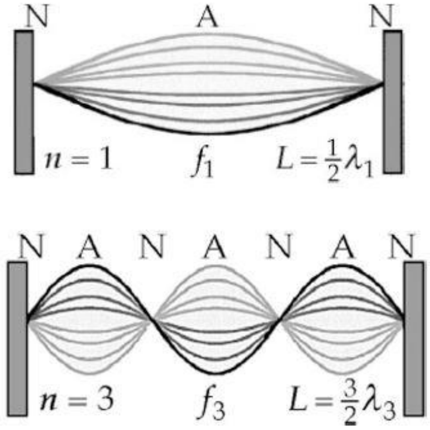
Chapter 18

P18.23 When the string vibrates in the lowest frequency mode, the length of string forms a standing wave where $L = \lambda/2$, so the fundamental harmonic wavelength is

$$\lambda = 2L = 2(0.700\text{ m})$$
$$= 1.40\text{ m}$$

and the speed is

$$v = \lambda f = (220\text{ s}^{-1})(1.40\text{ m})$$
$$= 308\text{ m/s}$$



ANS. FIG. P18.23

(a) From the tension equation

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{T}{m/L}}$$

we get $T = v^2 m/L$,

or $$T = \frac{(308\text{ m/s})^2(1.20 \times 10^{-3}\text{ kg})}{0.700\text{ m}} = \boxed{163\text{ N}}$$

(b) For the third harmonic, the tension, linear density, and speed are the same, but the string vibrates in three segments. Thus, the wavelength is one third as long as in the fundamental.

$$\lambda_3 = \lambda_1/3$$

From the equation $v = f\lambda$, we find the frequency is three times as high.

$$f_3 = \frac{v}{\lambda_3} = 3\frac{v}{\lambda_1} = 3f_1 = \boxed{660\text{ Hz}}$$

P18.33 Comparing $y = 0.002\ 00 \sin(\pi x)\cos(100\pi t)$ with $y = 2A \sin kx \cos \omega t$,

we find $k = \dfrac{2\pi}{\lambda} = \pi\ \text{m}^{-1} \rightarrow \lambda = 2.00\ \text{m}$, and

$$\omega = 2\pi f = 100\pi\ \text{s}^{-1} \rightarrow f = 50.0\ \text{Hz}$$

(a) The distance between adjacent nodes is $d_{\text{NN}} = \dfrac{\lambda}{2} = 1.00\ \text{m}$,

and on the string there are $\dfrac{L}{d_{\text{NN}}} = \dfrac{3.00\ \text{m}}{1.00\ \text{m}} = \boxed{3\ \text{loops}}$.

(b) For the speed we have $v = \omega/k = 100\pi\ \text{s}^{-1}/\pi\ \text{m}^{-1} = 100\ \text{m/s}$.

In the simplest standing wave vibration, $d_{\text{NN}} = 3.00\ \text{m} = \dfrac{\lambda_b}{2}$,

$\lambda_b = 6.00\ \text{m}$, and $f_b = \dfrac{v_a}{\lambda_b} = \dfrac{100\ \text{m/s}}{6.00\ \text{m}} = \boxed{16.7\ \text{Hz}}$.

(c) In $v_0 = \sqrt{\dfrac{T_0}{\mu}}$, if the tension increases to $T_c = 9T_0$ and the string does not stretch, the speed increases to

$$v_c = \sqrt{\frac{9T_0}{\mu}} = 3\sqrt{\frac{T_0}{\mu}} = 3v_0 = 3(100\ \text{m/s}) = 300\ \text{m/s}$$

Then $\lambda_c = \dfrac{v_c}{f_a} = \dfrac{300\ \text{m/s}}{50\ \text{Hz}} = 6.00\ \text{m}$, $\quad d_{\text{NN}} = \dfrac{\lambda_c}{2} = 3.00\ \text{m}$,

and $\boxed{\text{one loop}}$ fits onto the string.

P18.54 When the rod is clamped at one-quarter of its length, the vibration pattern reads ANANA and the rod length is $L = 2d_{\text{AA}} = \lambda$.

Therefore, $\quad L = \dfrac{v}{f} = \dfrac{5\ 100\ \text{m/s}}{4\ 400\ \text{Hz}} = \boxed{1.16\ \text{m}}$

P18.56 (a) The string could be tuned to either $\boxed{521\text{ Hz or }525\text{ Hz}}$ from this evidence.

(b) Tightening the string raises the wave speed and frequency. If the frequency were originally 521 Hz, the beats would slow down.

Instead, the frequency must have started at 525 Hz to become $\boxed{526\text{ Hz}}$.

(c) From $f = \frac{v}{\lambda} = \frac{\sqrt{T/\mu}}{2L} = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$,

$$\frac{f_2}{f_1} = \sqrt{\frac{T_2}{T_1}} \quad \text{and} \quad T_2 = \left(\frac{f_2}{f_1}\right)^2 T_1.$$

The fractional change that should be made in the tension is then

$$\text{fractional change} = \frac{T_2 - T_1}{T_1} = \frac{T_2}{T_1} - 1 = T_2 = \left(\frac{f_2}{f_1}\right)^2 - 1$$

$$= \left(\frac{523}{526}\right)^2 - 1 = -0.011\,4 = -1.14\%$$

The tension should be $\boxed{\text{reduced by }1.14\%}$.

P18.67 When the string is plucked, nodes occur on the ends because they are fixed. The plucked guitar string vibrates in its fundamental mode with a wavelength equal to twice the length of the string. For the 2 349-Hz note, the length of the vibrating string is $L = 21.4$ cm. For the 2 217-Hz note, the length of the vibrating string is $L + x$, where x is the distance to the next fret. We wish to solve for x.

We assume the wave speed is the same on each string. Compare the frequencies to the lengths of vibrating string:

$$f_1 = 2349 \text{ Hz} = \frac{v}{2L}$$

$$f_2 = 2217 \text{ Hz} = \frac{v}{2(L+x)}$$

Taking the ratio,

$$\frac{f_1}{f_2} = \frac{L+x}{L} = 1 + \frac{x}{L}$$

$$x = L\left(\frac{f_1}{f_2} - 1\right) = (21.4 \text{ cm})\left(\frac{2\ 349 \text{ Hz}}{2\ 217 \text{ Hz}} - 1\right) = \boxed{1.27 \text{ cm}}$$

P18.68 (a) The frequency of the normal mode produces a sound wave of the same frequency. For the same frequency, wavelength is proportional to wave speed. On the string, the wave speed is

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{(48.0 \text{ N})}{\left(\dfrac{4.80 \times 10^{-3} \text{ kg}}{2.00 \text{ m}}\right)}} = 141 \text{ m/s}$$

which is smaller than the speed of sound (343 m/s).

The wavelength in air of the sound produced by the string is $\boxed{\text{larger}}$ because the wave speed is larger.

(b) $$\frac{\lambda_{\text{air}}}{\lambda_{\text{string}}} = \frac{v_{\text{air}}/f}{v_{\text{string}}/f} = \frac{v_{\text{air}}}{v_{\text{string}}} = \frac{343 \text{ m/s}}{141 \text{ m/s}} = \boxed{2.43}$$

P18.77 We consider velocities of approach and of recession separately in the Doppler equation, after we observe from our beat equation $f_b = |f_1 - f_2| = |f - f'|$ that the moving train must have an apparent frequency of either $f' = 182$ Hz or $f' = 178$ Hz.

We let v_t represent the magnitude of the train's velocity. If the train is moving away from the station, the apparent frequency is 178 Hz, lower, as described by

$$f' = \frac{v}{v + v_t}$$

and the train is **moving away** at

$$v_t = v\left(\frac{f}{f'} - 1\right) = (343 \text{ m/s})\left(\frac{180 \text{ Hz}}{178 \text{ Hz}} - 1\right) = 3.85 \text{ m/s}$$

If the train is pulling into the station, then the apparent frequency is 182 Hz. Again from the Doppler shift,

$$f' = \frac{v}{v - v_s}$$

The train is **approaching** at

$$v_s = v\left(1 - \frac{f}{f'}\right) = (343 \text{ m/s})\left(1 - \frac{180 \text{ Hz}}{182 \text{ Hz}}\right)$$

$$v_s = 3.77 \text{ m/s}$$

The moving train has a velocity of either $\boxed{\text{3.85 m/s away from the station or 3.77 m/s toward the station}}$.

P18.80 (a) Since the first node is at the weld, the wavelength in the thin wire is $2L$ or 80.0 cm. The frequency and tension are the same in both sections, so

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}} = \frac{1}{2(0.400\ \text{m})}\sqrt{\frac{4.60\ \text{N}}{2.00 \times 10^{-3}\ \text{kg/m}}} = \boxed{59.9\ \text{Hz}}$$

(b) As the thick wire is twice the diameter, the linear density is 4 times that of the thin wire, or $\mu' = 8.00\ \text{g/m}$.

so

$$L' = \frac{1}{2f}\sqrt{\frac{T}{\mu'}}$$

$$= \left[\frac{1}{(2)(59.9\ \text{s}^{-1})}\right]\sqrt{\frac{4.60\ \text{N}}{8.00 \times 10^{-3}\ \text{kg/m}}} = \boxed{20.0\ \text{cm}}$$

or half the length of the thin wire.