P18.8 (a) $\Delta x = \sqrt{9.00 + 4.00} - 3.00 = \sqrt{13} - 3.00 = 0.606 \text{ m}$

The wavelength is $\lambda = \dfrac{v}{f} = \dfrac{343 \text{ m/s}}{300 \text{ Hz}} = 1.14 \text{ m}$

Thus, $\dfrac{\Delta x}{\lambda} = \dfrac{0.606}{1.14} = 0.530 \text{ of a wave}$,

or $\Delta\phi = 2\pi(0.530) = \boxed{3.33 \text{ rad}}$

(b) For destructive interference, we want $\dfrac{\Delta x}{\lambda} = 0.500 = f\dfrac{\Delta x}{v}$

where Δx is a constant in this set up. $f = \dfrac{v}{2\Delta x} = \dfrac{343}{2(0.606)} = \boxed{283 \text{ Hz}}$

P18.14 $y = 0.030\,0 \text{ m}\cos\left(\dfrac{x}{2}\right)\cos(40t)$

(a) nodes occur where $y = 0$:

$$\frac{x}{2} = (2n+1)\frac{\pi}{2}$$

so $x = \boxed{(2n+1)\pi = \pi,\ 3\pi,\ 5\pi,\ \ldots}$.

(b) $y_{\max} = 0.030\,0 \text{ m}\cos\left(\dfrac{0.400}{2}\right) = \boxed{0.029\,4 \text{ m}}$

P18.21 (a) Let n be the number of nodes in the standing wave resulting from the 25.0-kg mass. Then $n+1$ is the number of nodes for the standing wave resulting from the 16.0-kg mass. For standing waves, $\lambda = \dfrac{2L}{n}$, and the frequency is $f = \dfrac{v}{\lambda}$.

Thus, $f = \dfrac{n}{2L}\sqrt{\dfrac{T_n}{\mu}}$

and also $f = \dfrac{n+1}{2L}\sqrt{\dfrac{T_{n+1}}{\mu}}$

Thus, $\dfrac{n+1}{n} = \sqrt{\dfrac{T_n}{T_{n+1}}} = \sqrt{\dfrac{(25.0 \text{ kg})g}{(16.0 \text{ kg})g}} = \dfrac{5}{4}$

Therefore, $4n + 4 = 5n$, or $n = 4$

Then, $f = \dfrac{4}{2(2.00 \text{ m})}\sqrt{\dfrac{(25.0 \text{ kg})(9.80 \text{ m/s}^2)}{0.002\,00 \text{ kg/m}}} = \boxed{350 \text{ Hz}}$

(b) The largest mass will correspond to a standing wave of 1 loop

$(n = 1)$ so $350 \text{ Hz} = \dfrac{1}{2(2.00 \text{ m})}\sqrt{\dfrac{m(9.80 \text{ m/s}^2)}{0.002\,00 \text{ kg/m}}}$

yielding $m = \boxed{400 \text{ kg}}$

P18.38 The wavelength is $\lambda = \frac{v}{f} = \frac{343 \text{ m/s}}{261.6/\text{s}} = 1.31 \text{ m}$

so the length of the open pipe vibrating in its simplest (A-N-A) mode is

$$d_{\text{A to A}} = \frac{1}{2}\lambda = \boxed{0.656 \text{ m}}$$

A closed pipe has (N-A) for its simplest resonance,

(N-A-N-A) for the second,

and (N-A-N-A-N-A) for the third.

Here, the pipe length is $5d_{\text{N to A}} = \frac{5\lambda}{4} = \frac{5}{4}(1.31 \text{ m}) = \boxed{1.64 \text{ m}}$

P18.52 (a) The string could be tuned to either $\boxed{\text{521 Hz or 525 Hz}}$ 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 $\boxed{\text{526 Hz}}$.

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

$$\frac{f_2}{f_1} = \sqrt{\frac{T_2}{T_1}} \text{ and } T_2 = \left(\frac{f_2}{f_1}\right)^2 T_1 = \left(\frac{523 \text{ Hz}}{526 \text{ Hz}}\right)^2 T_1 = 0.989T_1.$$

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

$$\text{fractional change} = \frac{T_1 - T_2}{T_1} = 1 - 0.989 = 0.011\,4 = 1.14\% \text{ lower.}$$

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

P18.58 (a) Use the Doppler formula

$$f' = f\frac{(v \pm v_0)}{(v \mp v_s)}.$$

With f_1' = frequency of the speaker in front of student and

f_2' = frequency of the speaker behind the student.

$$f_1' = (456\text{ Hz})\frac{(343\text{ m/s} + 1.50\text{ m/s})}{(343\text{ m/s} - 0)} = 458\text{ Hz}$$

$$f_2' = (456\text{ Hz})\frac{(343\text{ m/s} - 1.50\text{ m/s})}{(343\text{ m/s} + 0)} = 454\text{ Hz}$$

Therefore, $f_b = f_1' - f_2' = \boxed{3.99\text{ Hz}}$.

(b) The waves broadcast by both speakers have $\lambda = \frac{v}{f} = \frac{343\text{ m/s}}{456/\text{s}} = 0.752\text{ m}$. The standing wave between them has $d_{AA} = \frac{\lambda}{2} = 0.376\text{ m}$. The student walks from one maximum to the next in time $\Delta t = \frac{0.376\text{ m}}{1.50\text{ m/s}} = 0.251\text{ s}$, so the frequency at which she hears maxima is $f = \frac{1}{T} = \boxed{3.99\text{ Hz}}$.

Chapter 34

P34.4 $\frac{E}{B} = c$

or $\frac{220}{B} = 3.00 \times 10^8$

so $B = 7.33 \times 10^{-7}\text{ T} = \boxed{733\text{ nT}}$.

P34.24 (a) $I = \frac{(10.0 \times 10^{-3})\text{ W}}{\pi(0.800 \times 10^{-3}\text{ m})^2} = \boxed{4.97\text{ kW/m}^2}$

(b) $u_{av} = \frac{I}{c} = \frac{4.97 \times 10^3\text{ J/m}^2 \cdot \text{s}}{3.00 \times 10^8\text{ m/s}} = \boxed{16.6\ \mu\text{J/m}^3}$

P34.30 (a) If is the total power radiated by the Sun, and r_E and r_M are the radii of the orbits of the planets Earth and Mars, then the intensities of the solar radiation at these planets are:

and .

Thus, $$I_M = I_E\left(\frac{r_E}{r_M}\right)^2 = \left(1\,340\ \text{W/m}^2\right)\left(\frac{1.496\times 10^{11}\ \text{m}}{2.28\times 10^{11}\ \text{m}}\right)^2 = \boxed{577\ \text{W/m}^2}.$$

(b) Mars intercepts the power falling on its circular face:

.

(c) If Mars behaves as a perfect absorber, it feels pressure $P = \frac{S_M}{c} = \frac{I_M}{c}$

and force .

(d) The attractive gravitational force exerted on Mars by the Sun is

$$F_g = \frac{GM_SM_M}{r_M^2} = \frac{\left(6.67\times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)\left(1.991\times 10^{30}\ \text{kg}\right)\left(6.42\times 10^{23}\ \text{kg}\right)}{\left(2.28\times 10^{11}\ \text{m}\right)^2} = 1.64\times 10^{21}\ \text{N}$$

which is $\boxed{\sim 10^{13}\ \text{times stronger}}$ than the repulsive force of part (c).

P34.37 (a) The magnetic field $\mathbf{B} = \frac{1}{2}\mu_0 J_{\max}\cos(kx-\omega t)\hat{\mathbf{k}}$ applies for $x > 0$, since it describes a wave moving in the $\hat{\mathbf{i}}$ direction. The electric field direction must satisfy $\mathbf{S} = \frac{1}{\mu_0}\mathbf{E}\times\mathbf{B}$ as $\hat{\mathbf{i}} = \hat{\mathbf{j}}\times\hat{\mathbf{k}}$ so the direction of the electric field is $\hat{\mathbf{j}}$ when the cosine is positive. For its magnitude we have $E = cB$, so altogether we have $\boxed{\mathbf{E} = \frac{1}{2}\mu_0 cJ_{\max}\cos(kx-\omega t)\hat{\mathbf{j}}}$.

(b) $$\mathbf{S} = \frac{1}{\mu_0}\mathbf{E}\times\mathbf{B} = \frac{1}{\mu_0}\frac{1}{4}\mu_0^2 cJ_{\max}^2\cos^2(kx-\omega t)\hat{\mathbf{i}}$$

$$\boxed{\mathbf{S} = \frac{1}{4}\mu_0 cJ_{\max}^2\cos^2(kx-\omega t)\hat{\mathbf{i}}}$$

(c) The intensity is the magnitude of the Poynting vector averaged over one or more cycles. The average of the cosine-squared function is $\frac{1}{2}$, so $\boxed{I = \frac{1}{8}\mu_0 cJ_{\max}^2}$.

(d) $$J_{\max} = \sqrt{\frac{8I}{\mu_0 c}} = \sqrt{\frac{8\left(570\ \text{W/m}^2\right)}{4\pi\times 10^{-7}\left(\text{Tm/A}\right)3\times 10^8\ \text{m/s}}} = \boxed{3.48\ \text{A/m}}$$