Homework 3

Chapter 17

P17.1 (a) $A = \boxed{2.00\ \mu\text{m}}$

(b) $\lambda = \dfrac{2\pi}{15.7} = 0.400\ \text{m} = \boxed{40.0\ \text{cm}}$

(c) $v = \dfrac{\omega}{k} = \dfrac{858}{15.7} = \boxed{54.6\ \text{m/s}}$

(d) $s = 2.00\cos\left[(15.7)(0.050\ 0) - (858)\left(3.00\times10^{-3}\right)\right] = \boxed{-0.433\ \mu\text{m}}$

(e) $v_{\text{max}} = A\omega = (2.00\ \mu\text{m})\left(858\ \text{s}^{-1}\right) = \boxed{1.72\ \text{mm/s}}$

P17.2 (a) $\Delta P = (1.27\ \text{Pa})\sin\left(\dfrac{\pi x}{\text{m}} - \dfrac{340\pi t}{\text{s}}\right)$ (SI units)

The pressure amplitude is: $\Delta P_{\text{max}} = \boxed{1.27\ \text{Pa}}$

(b) $\omega = 2\pi f = 340\pi/\text{s}$, so $f = \boxed{170\ \text{Hz}}$

(c) $k = \dfrac{2\pi}{\lambda} = \pi/\text{m}$, giving $\lambda = \boxed{2.00\ \text{m}}$

(d) $v = \lambda f = (2.00\ \text{m})(170\ \text{Hz}) = \boxed{340\ \text{m/s}}$

P17.10 $\Delta P_{\text{max}} = \rho v \omega s_{\text{max}}$

$$s_{\text{max}} = \frac{\Delta P_{\text{max}}}{\rho v \omega} = \frac{4.00\times10^{-3}\ \text{N/m}^2}{\left(1.20\ \text{kg/m}^3\right)(343\ \text{m/s})(2\pi)\left(10.0\times10^3\ \text{s}^{-1}\right)}$$

$$= \boxed{1.55\times10^{-10}\ \text{m}}$$

P17.11 (a) Since $v_{\text{light}} >> v_{\text{sound}}$, and assuming that the speed of sound is constant through the air between the lightning strike and the observer, we have

$$d \approx (343 \text{ m/s})(16.2 \text{ s}) = \boxed{5.56 \text{ km}}$$

(b) No, we do not need to know the value of the speed of light. The speed of light is much greater than the speed of sound, so the time interval required for the light to reach you is negligible compared to the time interval for the sound.

P17.18 Let d_1 represent the cowboy's distance from the nearer canyon wall and d_2 his distance from the farther cliff. The sound for the first echo travels distance $2d_1$. For the second, $2d_2$. For the third, $2d_1 + 2d_2$. For the fourth echo, $2d_1 + 2d_2 + 2d_1$. The time interval between the shot and the first echo is $\Delta t_1 = 2d_1/v$, between the shot and the second echo is $\Delta t_2 = 2d_2/v$, and so on.

Then

$$\Delta t_2 - \Delta t_1 = \frac{2d_2 - 2d_1}{343 \text{ m/s}} = 1.92 \text{ s and}$$

$$\Delta t_3 - \Delta t_2 = 1.47 \text{ s} \quad \rightarrow \quad \frac{(2d_1 + 2d_2) - 2d_2}{343 \text{ m/s}} = \frac{2d_1}{343 \text{ m/s}} = 1.47 \text{ s}$$

Thus, $d_1 = \frac{1}{2}(343 \text{ m/s})(1.47 \text{ s}) = 252 \text{ m}$, and $\Delta t_1 = 1.47 \text{ s}$

From above,

$$\Delta t_2 - \Delta t_1 = 1.92 \text{ s} \quad \rightarrow \quad \frac{2d_2}{343 \text{ m/s}} = 1.92 \text{ s} + 1.47 \text{ s}$$

which gives $d_2 = 581 \text{ m}$

(a) So, $d_1 + d_2 = \boxed{833 \text{ m}}$.

(b) $$\frac{2d_1 + 2d_2 + 2d_1 - (2d_1 + 2d_2)}{343 \text{ m/s}} = \frac{2d_2}{343 \text{ m/s}} = \boxed{1.47 \text{ s}}$$

P17.26 The decibel level due to the first siren is

$$\beta_1 = (10\text{ dB})\log\left(\frac{100.0\text{ W/m}^2}{1.0\times10^{-12}\text{ W/m}^2}\right) = 140\text{ dB}$$

Thus, the decibel level of the sound from the ambulance is

$$\beta_2 = \beta_1 + 10\text{ dB} = 140\text{ dB} + 10\text{ dB} = \boxed{150\text{ dB}}$$

P17.30 We begin with $\beta_2 = (10\text{ dB})\log\left(\frac{I_2}{I_0}\right)$ and $\beta_1 = (10\text{ dB})\log\left(\frac{I_1}{I_0}\right)$, so

$$\beta_2 - \beta_1 = (10\text{ dB})\log\left(\frac{I_2}{I_1}\right)$$

Also, $I_2 = \frac{P}{4\pi r_2^2}$ and $I_1 = \frac{P}{4\pi r_1^2}$, giving $\frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2$

Then, $\beta_2 - \beta_1 = (10\text{ dB})\log\left(\frac{r_1}{r_2}\right)^2 = \boxed{20\log\left(\frac{r_1}{r_2}\right)}$

P17.50 (a) The wavelength of the note is

$$\lambda = \frac{v}{f} = \frac{343\ \text{m/s}}{1\,480\ \text{s}^{-1}} = \boxed{0.232\ \text{m}}$$

(b) We find the intensity of the 81.0 dB sound from

$$\beta = 81.0\ \text{dB} = (10\ \text{dB})\log\left[\frac{I}{10^{-12}\ \text{W/m}^2}\right]$$

Then,

$$I = \left(10^{-12}\ \text{W/m}^2\right)10^{8.10} = 10^{-3.90}\ \text{W/m}^2 = 1.26\times 10^{-4}\ \text{W/m}^2$$
$$= \frac{1}{2}\rho v\omega^2 s_{\max}^2$$

Which gives a displacement amplitude of

$$s_{\max} = \sqrt{\frac{2I}{\rho v\omega^2}} = \sqrt{\frac{2\left(1.26\times 10^{-4}\ \text{W/m}^2\right)}{\left(1.20\ \text{kg/m}^3\right)\left(343\ \text{m/s}\right)4\pi^2\left(1\,480\ \text{s}^{-1}\right)^2}}$$
$$= \boxed{8.41\times 10^{-8}\ \text{m}}$$

(c) The wavelength of the F above high C is

$$\lambda' = \frac{v}{f'} = \frac{343\ \text{m/s}}{1\,397\ \text{s}^{-1}} = 0.246\ \text{m}$$

and the change in wavelength is

$$\Delta\lambda = \lambda' - \lambda = 0.246\ \text{m} - 0.232\ \text{m} = \boxed{13.8\ \text{mm}}$$

P17.52 We calculate the intensity of the speaker from

$$103\ \text{dB} = (10\ \text{dB})\log\left(\frac{I}{10^{-12}\ \text{W/m}^2}\right)$$

which gives $I = 2.00 \times 10^{-2}\ \text{W/m}^2$

(a) We find the sound power output from

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

which gives

$$P = 4\pi r^2 I = 4\pi(1.60\ \text{m})^2\left(2.00 \times 10^{-2}\ \text{W/m}^2\right) = \boxed{0.642\ \text{W}}$$

(b) The efficiency of the speaker is

$$e = \frac{P_{out}}{P_{in}} = \frac{0.642\ \text{W}}{150\ \text{W}} = \boxed{0.004}\ \text{ or }\ \boxed{0.4\%}$$

P17.68 The time interval required for a sound pulse to travel a distance L at a speed v is given by $t = \frac{L}{v} = \frac{L}{\sqrt{Y/\rho}}$. Using this expression, we find the travel time in each rod.

$$t_1 = L_1\sqrt{\frac{\rho_1}{Y_1}} = L_1\sqrt{\frac{2.70 \times 10^3\ \text{kg/m}^3}{7.00 \times 10^{10}\ \text{N/m}^2}} = L_1(1.96\times 10^{-4}\ \text{s/m})$$

$$t_2 = (1.50 - L_1)\sqrt{\frac{11.3 \times 10^3\ \text{kg/m}^3}{1.60 \times 10^{10}\ \text{N/m}^2}}$$
$$= 1.26\times 10^{-3}\ \text{s} - (8.40\times 10^{-4}\ \text{s/m})L_1$$

$$t_3 = (1.50\ \text{m})\sqrt{\frac{8.80 \times 10^3\ \text{kg/m}^3}{11.0 \times 10^{10}\ \text{N/m}^2}} = 4.24\times 10^{-4}\ \text{s}$$

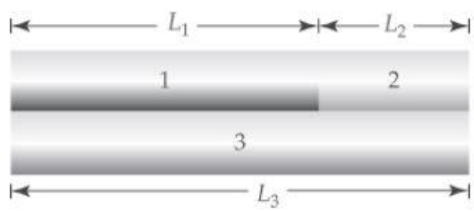
We require $t_1 + t_2 = t_3$, or

$$(1.96\times 10^{-4}\ \text{s/m})L_1 + (1.26\times 10^{-3}\ \text{s}) - (8.40\times 10^{-4}\ \text{s/m})L_1 = 4.24\times 10^{-4}\ \text{s}$$

This gives

$$L_1 = 1.30\ \text{m and } L_2 = (1.50\ \text{m}) - (1.30\ \text{m}) = 0.201\ \text{m}$$

The ratio of lengths is $\frac{L_1}{L_2} = \boxed{6.45}$.



ANS. FIG. P17.68