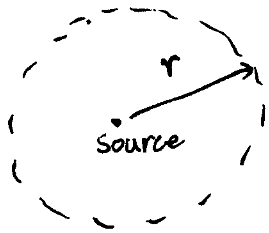
HW 4. Sound Waves

1. $$\text{Intensity} = \frac{\text{Power}}{\text{Area}} = \frac{P}{4\pi r^2}$$



If you take the sphere having the wave source inside of it, the intensity decreases ~~by~~ factor of $\frac{1}{r^2}$ as the radius increases by factor of r.

2.

3.

time difference between the clap of thunder and lightning, t is following.

$$t = \frac{\text{distance } d}{V_{sound}} - \frac{d}{V_{light}}$$

$$= \frac{d}{343} - \frac{d}{3\times10^8}$$

Very small

$$15.2s \approx \frac{d}{343}$$

$$\therefore d = 15.2 \times 343 \ m$$

4.

P17.6 It is easiest to solve part (b) first:

(b) The distance the sound travels to the plane is $d_s = \sqrt{h^2 + \left(\frac{h}{2}\right)^2} = \frac{h\sqrt{5}}{2}$.

The sound travels this distance in 2.00 s, so

$$d_s = \frac{h\sqrt{5}}{2} = (343\text{ m/s})(2.00\text{ s}) = 686\text{ m}$$

giving the altitude of the plane as $h = \frac{2(686\text{ m})}{\sqrt{5}} = \boxed{614\text{ m}}$.

(a) The distance the plane has traveled in 2.00 s is $v(2.00\text{ s}) = \frac{h}{2} = 307\text{ m}$.

Thus, the speed of the plane is: $v = \frac{307\text{ m}}{2.00\text{ s}} = \boxed{153\text{ m/s}}$.

5.

P17.11 (a) $A = \boxed{2.00\ \mu\text{m}}$

$$\lambda = \frac{2\pi}{15.7} = 0.400\text{ m} = \boxed{40.0\text{ cm}}$$

$$v = \frac{\omega}{k} = \frac{858}{15.7} = \boxed{54.6\text{ m/s}}$$

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

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

6.

P17.12 (a) $\Delta P = (1.27\text{ Pa})\sin\left(\frac{\pi x}{\text{m}} - \frac{340\pi t}{\text{s}}\right)$ (SI units)

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

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

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

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

7.

P17.15 $\Delta P_{max} = \rho v \omega s_{max} = \rho v\left(\frac{2\pi v}{\lambda}\right)s_{max}$

$$\lambda = \frac{2\pi\rho v^2 s_{max}}{\Delta P_{max}} = \frac{2\pi(1.20)(343)^2(5.50\times10^{-6})}{0.840} = \boxed{5.81\text{ m}}$$

8.

P17.21 $I = \frac{1}{2}\rho\omega^2 s_{max}^2 v$

(a) At $f = 2\,500$ Hz, the frequency is increased by a factor of 2.50, so the intensity (at constant s_{max}) increases by $(2.50)^2 = 6.25$.

Therefore, $6.25(0.600) = \boxed{3.75\ \text{W/m}^2}$.

(b) $\boxed{0.600\ \text{W/m}^2}$

9.

P17.29 Since intensity is inversely proportional to the square of the distance,

$$I_4 = \frac{1}{100}I_{0.4} \text{ and } I_{0.4} = \frac{\Delta P_{max}^2}{2\rho v} = \frac{(10.0)^2}{2(1.20)(343)} = 0.121\ \text{W/m}^2.$$

The difference in sound intensity level is

$$\Delta\beta = 10\log\left(\frac{I_{4\text{ km}}}{I_{0.4\text{ km}}}\right) = 10(-2.00) = -20.0\text{ dB}.$$

At 0.400 km,

$$\beta_{0.4} = 10\log\left(\frac{0.121\ \text{W/m}^2}{10^{-12}\ \text{W/m}^2}\right) = 110.8\text{ dB}.$$

At 4.00 km,

$$\beta_4 = \beta_{0.4} + \Delta\beta = (110.8 - 20.0)\text{ dB} = 90.8\text{ dB}.$$

Allowing for absorption of the wave over the distance traveled,

$$\beta_4' = \beta_4 - (7.00\ \text{dB/km})(3.60\text{ km}) = \boxed{65.6\text{ dB}}.$$

This is equivalent to the sound intensity level of heavy traffic.

10.

P17.31 We presume the speakers broadcast equally in all directions.

(a)

$$r_{AC}=\sqrt{3.00^2+4.00^2}\ \text{m}=5.00\ \text{m}$$

$$I=\frac{\wp}{4\pi r^2}=\frac{1.00\times10^{-3}\ \text{W}}{4\pi(5.00\ \text{m})^2}=3.18\times10^{-6}\ \text{W/m}^2$$

$$\beta=10\ \text{dB}\log\left(\frac{3.18\times10^{-6}\ \text{W/m}^2}{10^{-12}\ \text{W/m}^2}\right)$$

$$\beta=10\ \text{dB}\ 6.50=\boxed{65.0\ \text{dB}}$$

(b)

$$r_{BC}=4.47\ \text{m}$$

$$I=\frac{1.50\times10^{-3}\ \text{W}}{4\pi(4.47\ \text{m})^2}=5.97\times10^{-6}\ \text{W/m}^2$$

$$\beta=10\ \text{dB}\log\left(\frac{5.97\times10^{-6}}{10^{-12}}\right)$$

$$\beta=\boxed{67.8\ \text{dB}}$$

(c)

$$I=3.18\ \mu\text{W/m}^2+5.97\ \mu\text{W/m}^2$$

$$\beta=10\ \text{dB}\log\left(\frac{9.15\times10^{-6}}{10^{-12}}\right)=\boxed{69.6\ \text{dB}}$$

11.

P17.37 $$f'=f\frac{(v\pm v_O)}{(v\pm v_S)}$$

(a) $$f'=320\frac{(343+40.0)}{(343+20.0)}=\boxed{338\ \text{Hz}}$$

(b) $$f'=510\frac{(343+20.0)}{(343+40.0)}=\boxed{483\ \text{Hz}}$$

12.

P17.41 $$f'=f\left(\frac{v}{v-v_s}\right)$$

$$485=512\left(\frac{340}{340-(-9.80t_{\text{fall}})}\right)$$

$$485(340)+(485)(9.80t_f)=(512)(340)$$

$$t_f=\left(\frac{512-485}{485}\right)\frac{340}{9.80}=1.93\ \text{s}$$

$$d_1=\frac{1}{2}gt_f^2=18.3\ \text{m}:\qquad t_{\text{return}}=\frac{18.3}{340}=0.053\,8\ \text{s}$$

The fork continues to fall while the sound returns.

$$t_{\text{total fall}}=t_f+t_{\text{return}}=1.93\ \text{s}+0.053\,8\ \text{s}=1.985\ \text{s}$$

$$d_{\text{total}}=\frac{1}{2}gt_{\text{total fall}}^2=\boxed{19.3\ \text{m}}$$

13.

***P17.43** (a) Sound moves upwind with speed $(343-15)$ m/s. Crests pass a stationary upwind point at frequency 900 Hz.

Then $$\lambda = \frac{v}{f} = \frac{328\ \text{m/s}}{900/\text{s}} = \boxed{0.364\ \text{m}}$$

(b) By similar logic, $$\lambda = \frac{v}{f} = \frac{(343+15)\ \text{m/s}}{900/\text{s}} = \boxed{0.398\ \text{m}}$$

(c) The source is moving through the air at 15 m/s toward the observer. The observer is stationary relative to the air.

$$f' = f\left(\frac{v+v_o}{v-v_s}\right) = 900\ \text{Hz}\left(\frac{343+0}{343-15}\right) = \boxed{941\ \text{Hz}}$$

(d) The source is moving through the air at 15 m/s away from the downwind firefighter. Her speed relative to the air is 30 m/s toward the source.

$$f' = f\left(\frac{v+v_o}{v-v_s}\right) = 900\ \text{Hz}\left(\frac{343+30}{343-(-15)}\right) = 900\ \text{Hz}\left(\frac{373}{358}\right) = \boxed{938\ \text{Hz}}$$

14.

P17.45 The *half angle* of the shock wave cone is given by $\sin\theta = \frac{v_{\text{light}}}{v_S}$.

$$v_S = \frac{v_{\text{light}}}{\sin\theta} = \frac{2.25\times10^8\ \text{m/s}}{\sin(53.0°)} = \boxed{2.82\times10^8\ \text{m/s}}$$

15.

P17.60 Use the Doppler formula, and remember that the bat is a moving source.

If the velocity of the insect is v_x,

$$40.4 = 40.0\frac{(340+5.00)(340-v_x)}{(340-5.00)(340+v_x)}.$$

Solving,

$$v_x = 3.31\ \text{m/s}.$$

Therefore, $\boxed{\text{the bat is gaining on its prey at 1.69 m/s}}$.

16.

P17.64 The shock wavefront connects all observers first hearing the plane, including our observer O and the plane P, so here it is vertical. The angle ϕ that the shock wavefront makes with the direction of the plane's line of travel is given by

$$\sin\phi = \frac{v}{v_S} = \frac{340\ \text{m/s}}{1\,963\ \text{m/s}} = 0.173$$

so $\phi = 9.97°$.

Using the right triangle CPO, the angle θ is seen to be

$$\theta = 90.0° - \phi = 90.0° - 9.97° = \boxed{80.0°}.$$

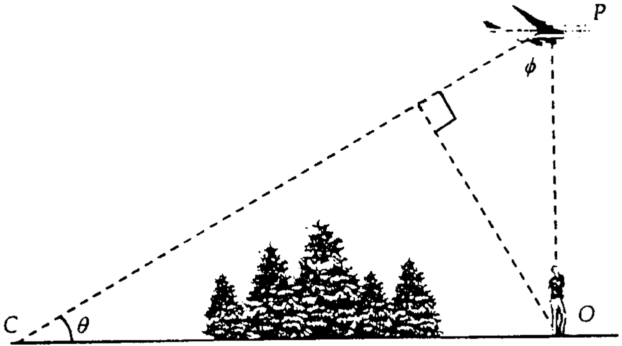


FIG. P17.64