Q: 1, 4, 5, 6, 9, 12, 14, 15

Questions

*Q17.1 Answer (b). The typically higher density would by itself make the speed of sound lower in a solid compared to a gas.

Q17.4 The speed of sound to two significant figures is 340 m/s. Let’s assume that you can measure time to $\frac{1}{10}$ second by using a stopwatch. To get a speed to two significant figures, you need to measure a time of at least 1.0 seconds. Since $d = vt$, the minimum distance is 340 meters.

*Q17.5 (i) Answer (b). The frequency increases by a factor of 2 because the wave speed, which is dependent only on the medium through which the wave travels, remains constant. (ii) Answer (c).

*Q17.9 Answer (d). The drop in intensity is what we should expect according to the inverse-square law: $4\pi r_1^2 P$ and $4\pi r_2^2 P$ should agree. $(300 \text{ m})^2 (2 \mu \text{W/m}^2)$ and $(950 \text{ m})^2 (0.2 \mu \text{W/m}^2)$ are 0.18 W and 0.18 W, agreeing with each other.

Q17.12 Our brave Siberian saw the first wave he encountered, light traveling at $3.00 \times 10^8$ m/s. At the same moment, infrared as well as visible light began warming his skin, but some time was required to raise the temperature of the outer skin layers before he noticed it. The meteor produced compressional waves in the air and in the ground. The wave in the ground, which can be called either sound or a seismic wave, traveled much faster than the wave in air, since the ground is much stiffer against compression. Our witness received it next and noticed it as a little earthquake. He was no doubt unable to distinguish the P and S waves from each other. The first air-compression wave he received was a shock wave with an amplitude on the order of meters. It transported him off his doorstep. Then he could hear some additional direct sound, reflected sound, and perhaps the sound of the falling trees.

*Q17.14 In $f' = (v + v_o)f/(v - v_s)$ we can consider the size of the fraction $(v + v_o)/(v - v_s)$ in each case. The positive direction is defined to run from the observer toward the source.

In (a), $340/340 = 1$ In (b), $340/(340 - 25) = 1.08$ In (c), $340/(340 + 25) = 0.932$ In (d), $(340+25)/340 = 1.07$ In (e), $(340-25)/340 = 0.926$ In (f) $(340 + 25)/(340 + 25) = 1$ In (g) $(340 - 25)/(340 - 25) = 1$. In order of decreasing size we have $b > d > a = f = g > c > e$.

*Q17.15 (i) Answer (c). Both observer and source have equal speeds in opposite directions relative to the medium, so in $f' = (v + v_o)f/(v - v_s)$ we would have something like $(340 - 25)f/(340 - 25) = f$.

(ii) Answer (a). The speed of the medium adds to the speed of sound as far as the observer is concerned, to cause an increase in $\lambda = v/f$.

(iii) Answer (a).
Problems: 3, 5, 7, 9, 11, 13, 17, 19, 23, 33, 38, 39, 41

*P17.3  The sound pulse must travel 150 m before reflection and 150 m after reflection. We have \( d = vt \)

\[
t = \frac{d}{v} = \frac{300 \text{ m}}{1533 \text{ m/s}} = 0.196 \text{ s}
\]

P17.5  Sound takes this time to reach the man:

\[
\frac{(20.0 \text{ m} - 1.75 \text{ m})}{343 \text{ m/s}} = 5.32 \times 10^{-2} \text{ s}
\]

so the warning should be shouted no later than \( 0.300 \text{ s} + 5.32 \times 10^{-2} \text{ s} = 0.353 \text{ s} \) before the pot strikes.

Since the whole time of fall is given by \( y = \frac{1}{2}gt^2 \):

\[
18.25 \text{ m} = \frac{1}{2}(9.80 \text{ m/s}^2)t^2
\]

\[
t = 1.93 \text{ s}
\]

the warning needs to come \( 1.93 \text{ s} - 0.353 \text{ s} = 1.58 \text{ s} \)

into the fall, when the pot has fallen

\[
\frac{1}{2}(9.80 \text{ m/s}^2)(1.58 \text{ s})^2 = 12.2 \text{ m}
\]

to be above the ground by

\[
20.0 \text{ m} - 12.2 \text{ m} = 7.82 \text{ m}
\]

7.  A cowboy stands on horizontal ground between two parallel vertical cliffs. He is not midway between the cliffs. He fires a shot, and hears its echoes. The second echo arrives 1.92 s after the first, and 1.47 s before the third. Consider only the sound traveling parallel to the ground and reflecting from the cliffs. Take the speed of sound as 340 m/s.

(a) What is the distance between the cliffs?  (b) What if?  If he can hear a fourth echo, how long after the third echo does it arrive?

*P17.7  Let \( x_1 \) represent the cowboy’s distance from the nearer canyon wall and \( x_2 \) his distance from the farther cliff. The sound for the first echo travels distance \( 2x_1 \). For the second, \( 2x_2 \). For the third,

\[
2x_1 + 2x_2 \text{. For the fourth echo, } 2x_1 + 2x_2 + 2x_1 \text{. Then } \frac{2x_2 - 2x_1}{340 \text{ m/s}} = 1.92 \text{ s and }
\]

\[
\frac{2x_1 + 2x_2 - 2x_2}{340 \text{ m/s}} = 1.47 \text{ s. Thus } x_1 = \frac{1}{2} \text{ 340 m/s 1.47 s = 250 m and } \frac{2x_2}{340 \text{ m/s}} = 1.92 \text{ s + 1.47 s;}
\]

\[
x_2 = 576 \text{ m} \text{.}
\]

(a)  So \( x_1 + x_2 = 826 \text{ m} \)

(b)  \[
\frac{2x_1 + 2x_2 + 2x_1 - (2x_1 + 2x_2)}{340 \text{ m/s}} = 1.47 \text{ s}
\]
*P17.9  
(a) If \( f = 2.4 \text{ MHz} \), \( \lambda = \frac{v}{f} = \frac{1500 \text{ m/s}}{2.4 \times 10^6 \text{s}} = \boxed{0.625 \text{ mm}} \) 
(b) If \( f = 1 \text{ MHz} \), \( \lambda = \frac{v}{f} = \frac{1500 \text{ m/s}}{10^6 \text{s}} = \boxed{1.50 \text{ mm}} \) 
If \( f = 20 \text{ MHz} \), \( \lambda = \frac{1500 \text{ m/s}}{2 \times 10^7 \text{s}} = \boxed{75.0 \text{ µm}} \)

P17.11  
(a) \( A = 2.00 \text{ µm} \) 
\[
\lambda = \frac{2\pi}{15.7} = 0.400 \text{ m} = \boxed{40.0 \text{ cm}} 
\]
\[
v = \frac{\omega}{k} = \frac{858}{15.7} = \boxed{54.6 \text{ m/s}} 
\]
(b) \( s = 2.00 \cos[(15.7)(0.0500) - (858)(3.00 \times 10^{-3})] = \boxed{-0.433 \text{ µm}} \)
(c) \( v_{\text{max}} = A \omega = (2.00 \text{ µm})(858 \text{ s}^{-1}) = \boxed{1.72 \text{ mm/s}} \)

13. Write an expression that describes the pressure variation as a function of position and time for a sinusoidal sound wave in air, if \( \lambda = 0.100 \text{ m} \) and \( \Delta P_{\text{max}} = 0.200 \text{ N/m}^2 \).

\[ k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.100 \text{ m}} = 62.8 \text{ m}^{-1} \] 
\[ \omega = \frac{2\pi v}{\lambda} = \frac{2\pi(343 \text{ m/s})}{0.100 \text{ m}} = 2.16 \times 10^4 \text{ s}^{-1} \] 
Therefore, \( \Delta P = (0.200 \text{ Pa})\sin[62.8x/m - 2.16 \times 10^4 \theta/s] \).

Write the function that describes the displacement wave corresponding to the pressure wave in Problem 13.

\[ \omega = 2\pi f = \frac{2\pi v}{\lambda} = \frac{2\pi(343 \text{ m/s})}{0.100 \text{ m}} = 2.16 \times 10^4 \text{ rad/s} \] 
\[ s_{\text{ax}} = \frac{\Delta P_{\text{max}}}{\rho \omega} = \frac{(0.200 \text{ Pa})}{(1.20 \text{ kg/m}^3)(343 \text{ m/s})(2.16 \times 10^4 \text{ s}^{-1})} = 2.25 \times 10^{-8} \text{ m} \] 
\[ k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.100 \text{ m}} = 62.8 \text{ m}^{-1} \] 
Therefore, \( s = s_{\text{ax}} \cos(kx - \omega t) = (2.25 \times 10^{-8} \text{ m}) \cos(62.8x/m - 2.16 \times 10^4 \theta/s) \).
P17.17 \[ \beta = 10 \log \left( \frac{I}{I_0} \right) = 10 \log \left( \frac{4.00 \times 10^{-6}}{1.00 \times 10^{-12}} \right) = 66.0 \text{ dB} \]

P17.19 \[ I = \frac{1}{2} \rho \omega^2 s^2_{\text{max}} v \]

(a) At \( f = 2 \, 500 \text{ Hz} \), the frequency is increased by a factor of 2.50, so the intensity (at constant \( s_{\text{max}} \)) increases by \( (2.50)^2 = 6.25. \)
Therefore, \( 6.25(0.600) = 3.75 \text{ W/m}^2 \)

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

23. A family ice show is held at an enclosed arena. The skaters perform to music with level 80.0 dB. This is too loud for your baby, who yells at 75.0 dB.
(a) What total sound intensity engulfs you? (b) What is the combined sound level?

P17.23 (a) \[ I_1 = \left( 1.00 \times 10^{-12} \text{ W} / \text{m}^2 \right) 10^{(\beta_1/10)} = \left( 1.00 \times 10^{-12} \text{ W} / \text{m}^2 \right) 10^{80/10} \]

or \[ I_1 = 1.00 \times 10^{-4} \text{ W} / \text{m}^2 \]

\[ I_2 = \left( 1.00 \times 10^{-12} \text{ W} / \text{m}^2 \right) 10^{(\beta_2/10)} = \left( 1.00 \times 10^{-12} \text{ W} / \text{m}^2 \right) 10^{75/10} \]

or \[ I_2 = 1.00 \times 10^{-45} \text{ W} / \text{m}^2 = 3.16 \times 10^{-5} \text{ W} / \text{m}^2 \]

When both sounds are present, the total intensity is
\[ I = I_1 + I_2 = 1.00 \times 10^{-4} \text{ W} / \text{m}^2 + 3.16 \times 10^{-5} \text{ W} / \text{m}^2 = 1.32 \times 10^{-4} \text{ W} / \text{m}^2. \]

(b) The decibel level for the combined sounds is
\[ \beta = 10 \log \left( \frac{1.32 \times 10^{-4} \text{ W} / \text{m}^2}{1.00 \times 10^{-12} \text{ W} / \text{m}^2} \right) = 10 \log \left( 1.32 \times 10^8 \right) = 81.2 \text{ dB}. \]
P17.26 We presume the speakers broadcast equally in all directions.

(a) \[ r_{AC} = \sqrt{3.00^2 + 4.00^2} \text{ m} = 5.00 \text{ m} \]
\[ I = \frac{P}{4\pi r^2} = \frac{1.00 \times 10^{-3} \text{ W}}{4\pi (5.00 \text{ m})^2} = 3.18 \times 10^{-6} \text{ W/m}^2 \]
\[ \beta = 10 \text{ dB} \log \left( \frac{3.18 \times 10^{-6} \text{ W/m}^2}{10^{-12} \text{ W/m}^2} \right) \]
\[ \beta = 10 \text{ dB} \ 6.50 = 65.0 \text{ dB} \]

(b) \[ r_{BC} = 4.47 \text{ m} \]
\[ I = \frac{1.50 \times 10^{-3} \text{ W}}{4\pi (4.47 \text{ m})^2} = 5.97 \times 10^{-6} \text{ W/m}^2 \]
\[ \beta = 10 \text{ dB} \log \left( \frac{5.97 \times 10^{-6}}{10^{-12}} \right) \]
\[ \beta = 67.8 \text{ dB} \]

(c) \[ I = 3.18 \mu \text{W/m}^2 + 5.97 \mu \text{W/m}^2 \]
\[ \beta = 10 \text{ dB} \log \left( \frac{9.15 \times 10^{-6}}{10^{-12}} \right) = 69.6 \text{ dB} \]

*P17.33 (a) \[ f' = \frac{f (v + v_o)}{(v - v_s)} \]
\[ f' = 2500 \left( \frac{343 + 25.0}{343 - 40.0} \right) = 3.04 \text{ kHz} \]

(b) \[ f' = 2500 \left( \frac{343 + (-25.0)}{343 - (-40.0)} \right) = 2.08 \text{ kHz} \]

(c) \[ f' = 2500 \left( \frac{343 + (-25.0)}{343 - 40.0} \right) = 2.62 \text{ kHz} \] while police car overtakes
\[ f' = 2500 \left( \frac{343 + 25.0}{343 - (-40.0)} \right) = 2.40 \text{ kHz} \] after police car passes
38. A siren mounted on the roof of a firehouse emits sound at a frequency of 900 Hz. A steady wind is blowing with a speed of 15.0 m/s. Taking the speed of sound in calm air to be 343 m/s, find the wavelength of the sound (a) upwind of the siren and (b) downwind of the siren. Firefighters are approaching the siren from various directions at 15.0 m/s. What frequency does a firefighter hear (c) if he or she is approaching from an upwind position, so that he is moving in the direction in which the wind is blowing? (d) if he or she is approaching from a downwind position and moving against the wind?

\[ \textit{P17.38} \]
(a) Sound moves upwind with speed \((343 - 15) \text{ m/s}\). Crests pass a stationary upwind point at frequency 900 Hz.

The speed of sound is
\[ v = \frac{328 \text{ m/s}}{900 \text{ s}} = 0.364 \text{ m} \]

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

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

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

(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.

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

\textit{P17.39} You have to do (b) first!

(b) \[ \sin \theta = \frac{v}{v_s} = \frac{3.00}{1} \]; \( \theta = 19.5^\circ \)

\[ \tan \theta = \frac{h}{x} \]

\[ x = \frac{h}{\tan \theta} \]

\[ x = \frac{20000 \text{ m}}{\tan 19.5^\circ} = 5.66 \times 10^4 \text{ m} = 56.6 \text{ km} \]

\[ \textit{It takes the plane} \ t = \frac{x}{v} = \frac{5.66 \times 10^4 \text{ m}}{3.00(335 \text{ m/s})} = 56.3 \text{ s} \] to travel this distance.