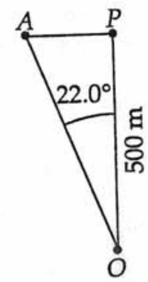
PROBLEM SET 2 CHAP 14.

10. Refer to Table 14.2 to see that a rock concert has an intensity level of about 120 dB, the turning of a page in a textbook about 30 dB, a normal conversation is about 50 dB, background noise at a church is about 30 dB. This leaves a cheering crowd at a football game to be about 60 dB.

14. A beam of radio waves of known frequency is sent toward a speeding car, which reflects the beam back to a detector in the police car. The amount the returning frequency has been shifted depends on the velocity of the oncoming car.



14.6 The speed of sound at $T = 10.0°\text{C} = 283\text{ K}$ is

$$v_a = (331\text{ m/s})\sqrt{\frac{T}{273\text{ K}}} = (331\text{ m/s})\sqrt{\frac{283\text{ K}}{273\text{ K}}} = 337\text{ m/s}$$

When the plane is at point P, the sound reaching the observer at O originated at point A and has traveled distance

$$\overline{OA} = \frac{\overline{OP}}{\cos(22.0°)} = \frac{500\text{ m}}{\cos(22.0°)} = 539\text{ m}$$

The transit time for this sound was $t = \frac{\overline{OA}}{v_s} = \frac{539\text{ m}}{337\text{ m/s}} = 1.60\text{ s}$. In this time interval, the plane traveled distance

$$\overline{AP} = \overline{OP}\tan(22.0°) = (500\text{ m})\tan(22.0°) = 202\text{ m},$$

so the speed of the plane is $v_p = \frac{\overline{AP}}{t} = \frac{202\text{ m}}{1.60\text{ s}} = \boxed{126\text{ m/s}}$

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14.13 From $\beta = 10\log(I/I_0)$, the intensity for sound level β is $I = I_0 10^{\beta/10}$.

The intensity of sound produced by one machine (β = 80 dB) is

$$I_1 = I_0\left(10^{8.0}\right)$$

The intensity needed to reach β = 90 dB is $I = I_0\left(10^{9.0}\right)$. Thus, the total number of machines the factory can accommodate without exceeding 90 dB is

$$N = \frac{I}{I_1} = \frac{I_0\left(10^{9.0}\right)}{I_0\left(10^{8.0}\right)} = 10$$

Since the factory already contains one of these machines, you can add $\boxed{\text{9 additional machines}}$ without going over the limit.

14.16 (a) $I = \dfrac{\wp}{4\pi r^2} = \dfrac{100\ \text{W}}{4\pi\,(10.0\ \text{m})^2} = \boxed{7.96\times10^{-2}\ \text{W/m}^2}$

(b) $\beta = 10\log\left(\dfrac{I}{I_0}\right) = 10\log\left(\dfrac{7.96\times10^{-2}\ \text{W/m}^2}{1.00\times10^{-12}\ \text{W/m}^2}\right)$

$$= 10\log\left(7.96\times10^{10}\right) = \boxed{109\ \text{dB}}$$

(c) At the threshold of pain (β = 120 dB), the intensity is $I = 1.00\ \text{W/m}^2$. Thus, from $I = \wp/4\pi r^2$, the distance from the speaker is

$$r = \sqrt{\frac{\wp}{4\pi I}} = \sqrt{\frac{100\ \text{W}}{4\pi\left(1.00\ \text{W/m}^2\right)}} = \boxed{2.82\ \text{m}}$$

14.23 Both source and observer are in motion, so $f' = f\left(\dfrac{v+v_o}{v-v_s}\right)$. Since each train moves *toward* the other, $v_o > 0$ and $v_s > 0$. The speed of the source (train 2) is

$$v_s = 90.0\ \frac{\text{km}}{\text{h}}\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 25.0\ \text{m/s}$$

and that of the observer (train 1) is $v_o = 130\ \text{km/h} = 36.1\ \text{m/s}$. Thus, the observed frequency is

$$f' = (500\ \text{Hz})\left(\frac{345\ \text{m/s} + 36.1\ \text{m/s}}{345\ \text{m/s} - 25.0\ \text{m/s}}\right) = \boxed{595\ \text{Hz}}$$

14.32 The wavelength of the sound produced by the speakers is

$$\lambda = \frac{v}{f} = \frac{345 \text{ m/s}}{500 \text{ Hz}} = 0.690 \text{ m}$$

(a) To produce destructive interference, the speaker should be moved back a distance of $d = \frac{\lambda}{2} = \boxed{0.345 \text{ m}}$.

(b) The speakers will now be separated by a full wavelength and $\boxed{\text{constructive interference}}$ will again occur.

14.37 The facing speakers produce a standing wave in the space between them, with the spacing between nodes being

$$d_{\text{NN}} = \frac{\lambda}{2} = \frac{1}{2}\left(\frac{v}{f}\right) = \frac{343 \text{ m/s}}{2(800 \text{ Hz})} = 0.214 \text{ m}.$$

If the speakers vibrate in phase, the point halfway between them is an

antinode of pressure, at $\frac{1.25 \text{ m}}{2} = 0.625 \text{ m}$ from either speaker.

Then there is a node at $0.625 \text{ m} - \frac{0.214 \text{ m}}{2} = \boxed{0.518 \text{ m}}$,

a node at $0.518 \text{ m} - 0.214 \text{ m} = \boxed{0.303 \text{ m}}$,

a node at $0.303 \text{ m} - 0.214 \text{ m} = \boxed{0.0891 \text{ m}}$,

a node at $0.518 \text{ m} + 0.214 \text{ m} = \boxed{0.732 \text{ m}}$,

a node at $0.732 \text{ m} + 0.214 \text{ m} = \boxed{0.947 \text{ m}}$, and

a node at $0.947 \text{ m} + 0.214 \text{ m} = \boxed{1.16 \text{ m}}$ from one speaker.

14.44 (a) In the fundamental resonant mode of a pipe open at both ends, the distance between antinodes is $d_{AA} = \lambda/2 = L$.

Thus, $\lambda = 2L = 2(0.320\text{ m}) = 0.640\text{ m}$

and $$f = \frac{v}{\lambda} = \frac{340\text{ m/s}}{0.640\text{ m}} = \boxed{531\text{ Hz}}$$

(b) $$d_{AA} = \frac{\lambda}{2} = \frac{1}{2}\left(\frac{v}{f}\right) = \frac{1}{2}\left(\frac{340\text{ m/s}}{4\,000\text{ Hz}}\right) = 0.0425\text{ m} = \boxed{4.25\text{ cm}}$$

14.48 For a pipe open at both ends, the frequency of the nth harmonic is, $f_n = n(v/2L)$. Thus, the difference between two successive resonant frequencies is

$$\Delta f = f_{n+1} - f_n = (n+1)\left(\frac{v}{2L}\right) - n\left(\frac{v}{2L}\right) = \frac{v}{2L}$$

In this case, $L = 2.00\text{ m}$ and $\Delta f = 492\text{ Hz} - 410\text{ Hz} = 82\text{ Hz}$. Thus, the speed of sound in the pipe is

$$v = 2L(\Delta f) = 2(2.00\text{ m})(82\text{ Hz}) = \boxed{3.3\times10^2\text{ m/s}}$$