CHAPTER FOURTEEN SOLUTIONS

14.3 The speed of sound at 27 °C is: $v = (331 \text{ m/s})\sqrt{1 + \frac{27}{273}} = 347 \frac{\text{m}}{\text{s}}$.

Thus, the wavelengths are: $\lambda_{20 \text{ Hz}} = \frac{v}{f} = \frac{347 \text{ m/s}}{20.0 \text{ Hz}} = 17.3 \text{ m}$, and

$$\lambda_{20,000 \text{ Hz}} = \frac{v}{f} = \frac{347 \text{ m/s}}{2.0 \times 10^4 \text{ Hz}} = 1.7 \times 10^{-2} \text{ m.}$$

14.7 (a) $P = IA = I(5.0 \times 10^{-5} \text{ m}^2)$. At the threshold of hearing, $I = 10^{-12}$ W/m^2. Thus, $P = (10^{-12} \text{ W/m}^2)(5.0 \times 10^{-5} \text{ m}^2) = 5.0 \times 10^{-17}$ W.

(b) At the threshold of pain, $I = 1 \text{ W/m}^2$.

$P = (1.0 \text{ W/m}^2)(5.0 \times 10^{-5} \text{ m}^2) = 5.0 \times 10^{-5}$ W.

14.12 (a) $I = \frac{P}{4\pi r^2} = \frac{100 \text{ W}}{4\pi(10.0 \text{ m})^2} = 7.96 \times 10^{-2} \text{ W/m}^2$.

(b) $\beta = 10 \log\left(\frac{7.96 \times 10^{-2}}{10^{-12}}\right) = 10 \log(7.96 \times 10^{10}) = 109$ dB

(c) If $\beta = 120$ dB (the threshold of pain), $I = 1 \text{ W/m}^2$, and from $I = \frac{P}{4\pi r^2}$,

and we find: $r^2 = \frac{P}{4\pi I} = \frac{100 \text{ W}}{4\pi(1 \text{W/m}^2)} = 7.96 \text{ m}^2$, giving: $r = 2.82$ m.

14.20 The wall will reflect a frequency of f_{wall} given by (source approaches a stationary observer): $f_{\text{wall}} = (40 \text{ kHz})\frac{345 \text{ m/s}}{345 \text{ m/s} - 5.0 \text{ m/s}} = 40.6$ kHz.

Treating the wall as a stationary source of sound having frequency 40.6 kHz, we have for the return signal (observer approaching stationary source):

$$f'_{\text{bat}} = (40.6 \text{ kHz})\frac{345 \text{ m/s} + 5.0 \text{ m/s}}{345 \text{ m/s}} = 41 \text{ kHz.}$$

14.21 When the train is moving toward the observer at a speed v, we have

$$442 \text{ Hz} = f\frac{345}{345 - v} \quad . \qquad (1)$$

When the train is moving away from the observer, at v, we have

$$441 \text{ Hz} = f\frac{345}{345 + v} \quad . \qquad (2)$$

Divide equation (1) by (2), f cancels, and the resulting equation can be solved for v. We find: $v = 0.391$ m/s.

14.27 Since $f = 690$ Hz, we have $\lambda = \frac{345 \text{ m/s}}{690 \text{ Hz}} = 0.500$ m.

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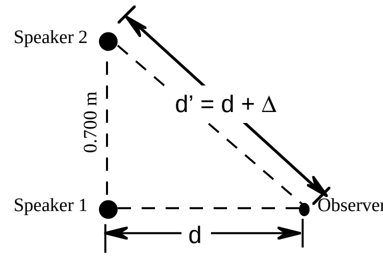
(a) At the first relative maximum (constructive interference), $\Delta = \lambda = 0.500$ m.
Thus, the Pythagorean theorem gives

$(d + 0.500\text{ m})^2 = (0.700\text{ m})^2 + d^2$,
or $d = 0.240$ m.



(b) At the first relative minimum (destructive interference), $\Delta = \lambda/2 = 0.250$ m. Therefore,
$(d + 0.250\text{ m})^2 = (0.700\text{ m})^2 + d^2$,
or $d = 0.855$ m.

14.37 (a) The space between successive resonance points is $\lambda/2$. Therefore, $\lambda/2 = (0.24\text{ m} - 0.080\text{ m}) = 0.16$ m, or $\lambda = 0.32$ m.
The third resonance point will be one-half wavelength further down the tube. This location is at 0.24 m + 0.16 m = 0.40 m.

(b) $f = \dfrac{v}{\lambda} = \dfrac{345\text{ m/s}}{0.32\text{ m}} = 1.1\times10^3$ Hz.

14.38 For the open pipe (and the fundamental mode):

$\lambda = \dfrac{v}{f} = \dfrac{345\text{ m/s}}{261.6\text{ Hz}} = 1.319$ m, and $L = \dfrac{\lambda}{2} = 0.659$ m = 65.9 cm.

For the closed pipe (and the third harmonic), $\lambda = \dfrac{v}{f} = \dfrac{345\text{ m/s}}{261.6\text{ Hz}} = 1.319$ m,

and $L = \dfrac{3}{4}(1.319\text{ m}) = 0.989$ m = 98.9 cm.

14.39 Hearing would be best at the fundamental resonance, so we take

$f_n = \dfrac{nv}{4L} = \dfrac{(1)(340)}{4(0.028)} = 3.0\times10^3$ Hz

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14.43 The speed of transverse waves in a string is $v = \sqrt{\dfrac{T}{\mu}}$.

Thus for $T = 200$ N, $v = \sqrt{\dfrac{200\text{ N}}{\mu}}$, and for $T = 196$ N, $v' = \sqrt{\dfrac{196\text{ N}}{\mu}}$.

Since $v = \lambda f$ and the length of the string (and hence λ) does not change:

$\dfrac{f'}{f} = \dfrac{v'}{v}$, or $f' = \sqrt{\dfrac{196\text{ N}}{\mu}\,\dfrac{\mu}{200\text{ N}}}\; f = 0.99(523\text{ Hz})$, giving $f' = 517.7$ Hz.

The beat frequency is $f_{beat} = f - f' = (523 - 517.7)\text{Hz} = 5.26$ Hz

ANSWERS TO EVEN ASSIGNED CONCEPTUAL QUESTIONS

8. 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.

12. 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.