ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. All sound waves travel at the same speed in air of a given temperature. Thus, $v = \lambda f = \lambda_2 f_2$, giving

$$f_2 = \left(\frac{\lambda}{\lambda_2}\right) f = \left(\frac{\lambda}{\lambda/2}\right) f = 2f$$

and the correct choice is (b).

2. The answer to this question may be found from Table 14.1 in the textbook, which gives $v_{\text{Al}} = 5\ 100\ \text{m/s}$. It can also be computed from Equation 14.3, using data from Tables 9.1 and 9.3, which gives

$$v_{\text{Al}} = \sqrt{\frac{Y_{\text{Al}}}{\rho_{\text{Al}}}} = \sqrt{\frac{7.0 \times 10^{10}\ \text{Pa}}{2.7 \times 10^{3}\ \text{kg/m}^3}} = 5.1 \times 10^{3}\ \text{m/s}$$

Both methods show that choice (e) is the correct answer.

3. The speed of sound in a fluid is given in Equation 14.1 as $v = \sqrt{B/\rho}$, where B is the bulk modulus of the fluid and ρ is its density. The density of ethyl alcohol may be found in Table 9.3 of the textbook. Then, the speed of sound in ethyl alcohol is found to be

$$v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{1.0 \times 10^{9}\ \text{Pa}}{0.806 \times 10^{3}\ \text{kg/m}^3}} = 1.1 \times 10^{3}\ \text{m/s}$$

and (a) is the correct choice.

4. The Celsius temperature on this day was $T_{\text{C}} = \frac{5}{9}(T_{\text{F}} - 32) = \frac{5}{9}(134 - 32) = 56.7°\text{C}$, and the absolute temperature was $T_K = T_C + 273 = 56.7 + 273 = 330$ K. The speed of sound in the air was

$$v = (331\ \text{m/s})\sqrt{\frac{T_{\text{K}}}{273\ \text{K}}} = (331\ \text{m/s})\sqrt{\frac{330\ \text{K}}{273\ \text{K}}} = 364\ \text{m/s}$$

and the correct answer is (c).

5. In a uniform medium, the intensity of sound varies inversely with the square of the distance from the source

(See Equation 14.8 in the textbook.) Thus, if the distance from the source is tripled, the new sound intensity will be
one–ninth of its original value, making (a) the correct choice.

6. The relation between the decibel level and the sound intensity is $\beta = 10 \cdot \log\left(I/I_0\right)$, where the reference intensity is $I_0 = 1.0 \times 10^{-12}\ \text{W/m}^2$ and log refers to the base 10 logarithm. Thus, if β = 105 dB, the sound intensity is

$$I = I_0 \cdot 10^{\beta/10} = \left(1.0 \times 10^{-12}\ \text{W/m}^2\right) \cdot 10^{10.5} = 3.16 \times 10^{-2}\ \text{W/m}^2$$

and (d) is the correct answer.

7. The apparent frequency f_0 detected by an observer from a source emitting sound of frequency f_S is given by

$$f_O = f_S\left(\frac{v + v_O}{v - v_S}\right)$$

where v is the speed of sound in air, v_O is the velocity of the observer relative to the air and is positive is the observer moves toward the source, while v_S is the velocity of the source relative to the air and is positive if the source moves toward the observer. In this case, we have

$$f_O = \left(1.00 \times 10^3\ \text{Hz}\right)\left[\frac{340\ \text{m/s} + \left(-30.0\ \text{m/s}\right)}{340\ \text{m/s} - \left(+50.0\ \text{m/s}\right)}\right] = 1.07 \times 10^3\ \text{m/s}$$

so the correct choice is (d).

8. At resonance, a tube closed at one end and open at the other forms a standing wave pattern with a node at the closed end and antinode at the open end. In the fundamental mode (or first harmonic), the length of the length of the tube closed at one end is a quarter wavelength $\left(L = \lambda_1/4 \text{ or } \lambda_1 = 4L\right)$. Therefore, for the given tube, λ_1 = 4(0.580 m) = 2.32 m and the fundamental frequency is

$$f_1 = \frac{v}{\lambda_1} = \frac{343\ \text{m/s}}{2.32\ \text{m}} = 148\ \text{Hz}$$

and the correct answer is choice (a).

9. The number of beats per second (the beat frequency) equals the difference in the frequencies of the two tuning forks. Thus, if the beat frequency is 5 Hz and one fork is known to have a frequency of 245 Hz, the frequency of the second fork could be either $f_2 = 245\text{ Hz} - 5\text{ Hz} = 240\text{ Hz}$ or $f_2 = 245\text{ Hz} + 5\text{ Hz} = 250\text{ Hz}$. This means that the best answer for the question is choice (e), since choices (a) and (d) are both possibly correct.

10. When a sound wave travels from air into water, several properties will change. The wave speed will increase as the wave crosses the boundary into the water, the spacing between crests (the wavelength) will increase since crests move away from the boundary faster than they move up to the boundary, and the sound intensity in the water will be less than it was in air because some sound is reflected by the water surface. However, the frequency (number of crests passing each second) will be unchanged, since a crest moves away from the boundary every time a crest arrives at the boundary. Among the listed choices, the only correct statement is choice (d).

11. When the two ends of a pipe are alike (either both open or both closed), all harmonics (integer multiples of the fundamental frequency) are present among the resonant frequencies of the pipe. However, in a pipe closed at one end and open at the other, only the odd harmonics (i.e., only *odd integer* multiples of the fundamental frequency) are resonant frequencies for the pipe. In the case of the given pipe, the fundamental frequency is $f_1 = 150\text{ Hz}$, and both $f_2 = 2f_1 = 300\text{ Hz}$ (an even multiple) and $f_3 = 3f_1 = 450\text{ Hz}$ (an odd multiple) are resonant frequencies. Thus, the pipe must have either two open ends or two closed ends, and the correct choice is (b).

12. The ambulance driver, sitting at a fixed distance from the siren, hears the actual frequency emitted by the siren. However, the distance between you and the siren is decreasing, so you will detect a frequency higher than the actual 500 Hz. Choice (c) is the correct answer.

13. The speed of sound in air, at atmospheric pressure, is determined by the temperature of the air and does not depend on the frequency of the sound. Sound from siren *A* will have a wavelength that is half the wavelength of the sound from *B*, but the speed of the sound (the product of frequency times wavelength) will be the same for the two sirens. The correct choice is (e).

14. In the fundamental mode (first harmonic), a pipe open at both ends has antinodes at each end and a node at the center. The wavelength of this harmonic is $\lambda_1 = 2L$ and the resonant frequency is $f_{\text{open}} = v/2L$. If one end of the pipe is now closed, the fundamental mode will have a node at the closed end with an antinode at the open end. The wavelength of the first harmonic is $\lambda_1' = 4L$ and the resonant frequency is $f_{\text{closed}} = v/4L$. Thus, we see that $f_{\text{open}} = 2f_{\text{closed}}$ and the correct choice is (b).

15. Doubling the power output of the source will double the intensity of the sound at the observer's location. The original decibel level of the sound is $\beta = 10 \cdot \log\left(I/I_0\right)$. After doubling the power output and intensity, the new decibel level will be

$$\beta' = 10 \cdot \log\left(2I/I_0\right) = 10 \cdot \log\left[2\left(I/I_0\right)\right] = 10 \cdot \left[\log 2 + \log\left(I/I_0\right)\right] = 10 \cdot \log 2 + \beta$$

so the increase in decibel level is $\beta' - \beta = 10 \cdot \log 2 = 3.0$ dB, making (c) the correct answer.