Chapter 12

SOUND

Problems

1. Strategy Use Eqs. (11-6) and (12-3).

Solution Find the wavelength of the ultrasonic waves.

$$\lambda = \frac{v}{f} \text{ and } v = v_0\sqrt{\frac{T}{T_0}}, \text{ so } \lambda = \frac{v}{f} = \frac{v_0}{f}\sqrt{\frac{T}{T_0}} = \frac{331\ \text{m/s}}{1.0\times10^5\ \text{Hz}}\sqrt{\frac{273.15\ \text{K} + 15\ \text{K}}{273.15}} = \boxed{3.4\ \text{mm}}.$$

9. Strategy Replace each quantity with its SI units and simplify. In (a), use Eq. (12-1). In (b), analyze each combination of ρ and B.

Solution

(a) Show that Eq. (12-1) gives the speed of sound in m/s.

$$v = \sqrt{\frac{B}{\rho}}, \text{ so } \sqrt{\frac{\text{N/m}^2}{\text{kg/m}^3}} = \sqrt{\frac{(\text{kg}\cdot\text{m/s}^2)/\text{m}^2}{\text{kg/m}^3}} = \sqrt{\frac{1/(\text{m}\cdot\text{s}^2)}{1/\text{m}^3}} = \sqrt{\frac{\text{m}^2}{\text{s}^2}} = \text{m/s}.$$

(b) Show that no other combination of B and ρ of than $\sqrt{B/\rho}$ can give dimensions of speed.

$$\frac{\rho}{B} \text{ has units } \frac{\text{kg}}{\text{m}^3}\cdot\frac{\text{m}^2}{\text{N}} = \frac{\text{kg}}{\text{m}\cdot\text{kg}\cdot\text{m/s}^2} = \frac{\text{s}^2}{\text{m}^2};\ \ \rho B \text{ has units } \frac{\text{kg}}{\text{m}^3}\cdot\frac{\text{N}}{\text{m}^2} = \frac{\text{kg}^2\cdot\text{m/s}^2}{\text{m}^5} = \frac{\text{kg}^2}{\text{m}^4\cdot\text{s}^2};\ \text{and}$$

$$\frac{1}{\rho B} \text{ has units } \frac{\text{m}^4\cdot\text{s}^2}{\text{kg}^2}.$$

No power of the above three combinations (other than $-1/2$, which gives $\sqrt{B/\rho}$) will give the dimensions of speed; therefore, Eq. (12-1) must be correct except for the possibility of a dimensionless constant.

23. Strategy $f_n = nv/(2L)$ for a pipe open at both ends.

Solution Find the length of the organ pipe.

$$f_1 = \frac{v}{2L}, \text{ so } L = \frac{v}{2f_1} = \frac{331\ \text{m/s}}{2(382\ \text{Hz})} = \boxed{43.3\ \text{cm}}.$$

37. Strategy Since the observer is moving and the source is stationary, use Eq. (12-13).

Solution As Mandy walks toward one siren (1), $v_\text{o} < 0$. As she recedes from the other siren (2), $v_\text{o} > 0$. Find the beat frequency heard by Mandy.

$$f_1 - f_2 = \left(1 + \frac{|v_\text{o}|}{v}\right)f_\text{s} - \left(1 - \frac{|v_\text{o}|}{v}\right)f_\text{s} = \frac{2|v_\text{o}|\,f_\text{s}}{v} = \frac{2(1.56\ \text{m/s})(698\ \text{Hz})}{343\ \text{m/s}} = \boxed{6.35\ \text{Hz}}$$

47. Strategy The distance traveled (round trip) by the sound wave in time Δt is $v\Delta t$. The depth d of the lake is half this distance.

Solution Find the depth of the lake.

$$d = \frac{1}{2}v\Delta t = \frac{1}{2}(0.540\ \text{s})(1493\ \text{m/s}) = \boxed{403\ \text{m}}$$

61. **Strategy** The distance traveled (round trip) by the sound pulse in time Δt is $v\Delta t$. The distance to the ocean floor is half this distance.

Solution Find the elapsed time between an emitted pulse and the return of its echo at the correct depth d.

$$2d = v\Delta t,\ \text{so}\ \Delta t = \frac{2d}{v} = \frac{2(40.0\ \text{fathoms})\left(1.83\ \frac{\text{m}}{\text{fathom}}\right)}{1533\ \text{m/s}} = \boxed{0.0955\ \text{s}}.$$