Solutions to Problems

2. The mass is found from the density of air (found in Table 13-1) and the volume of air.

$$m = \rho V = \left(1.29\,\mathrm{kg/m^3}\right)\left(5.6\,\mathrm{m}\right)\left(3.8\,\mathrm{m}\right)\left(2.8\,\mathrm{m}\right) = \boxed{77\,\mathrm{kg}}$$

4. Assume that your density is that of water, and that your mass is 75 kg.

$$V = \frac{m}{\rho} = \frac{75\ \mathrm{kg}}{1.00\times10^{3}\ \mathrm{kg/m^3}} = \boxed{7.5\times10^{-2}\,\mathrm{m^3}} = 75\ \mathrm{L}$$

9. (*a*) The pressure exerted on the floor by the chair leg is caused by the chair pushing down on the floor. That downward push is the reaction to the normal force of the floor on the leg, and the normal force on one leg is assumed to be one-fourth of the weight of the chair.

$$P_{\text{chair}} = \frac{W_{\text{leg}}}{A} = \frac{\frac{1}{4}\left(66\,\mathrm{kg}\right)\left(9.80\,\mathrm{m/s^2}\right)}{\left(0.020\,\mathrm{cm^2}\right)\left(\frac{1\,\mathrm{m}}{100\,\mathrm{cm}}\right)^2} = 8.085\times10^{7}\ \mathrm{N/m^2} \approx \boxed{8.1\times10^{7}\ \mathrm{N/m^2}}.$$

(*b*) The pressure exerted by the elephant is found in the same way, but with ALL of the weight being used, since the elephant is standing on one foot.

$$P_{\text{elephant}} = \frac{W_{\text{elephant}}}{A} = \frac{\left(1300\,\mathrm{kg}\right)\left(9.80\,\mathrm{m/s^2}\right)}{\left(800\,\mathrm{cm^2}\right)\left(\frac{1\ \mathrm{m}}{100\ \mathrm{cm}}\right)^2} = 1.59\times10^{5}\ \mathrm{N/m^2} \approx \boxed{2\times10^{5}\ \mathrm{N/m^2}}.$$

Note that the chair pressure is larger than the elephant pressure by a factor of about 400.

10. Use Eq. 13-3 to find the pressure difference. The density is found in Table 13-1.

$$P = \rho g h \ \rightarrow\ \Delta P = \rho g \Delta h = \left(1.05\times10^{3}\ \mathrm{kg/m^3}\right)\left(9.80\,\mathrm{m/s^2}\right)\left(1.70\,\mathrm{m}\right)$$

$$= 1.749\times10^{4}\ \mathrm{N/m^2}\left(\frac{1\ \text{mm-Hg}}{133\,\mathrm{N/m^2}}\right) = \boxed{132\ \text{mm-Hg}}$$

15. (*a*) The absolute pressure is given by Eq. 13-6b, and the total force is the absolute pressure times the area of the bottom of the pool.

$$P = P_0 + \rho g h = 1.013\times10^5\ \mathrm{N/m^2} + \left(1.00\times10^3\ \mathrm{kg/m^3}\right)\left(9.80\ \mathrm{m/s^2}\right)\left(1.8\ \mathrm{m}\right)$$
$$= 1.189\times10^5\ \mathrm{N/m^2} \approx \boxed{1.2\times10^5\ \mathrm{N/m^2}}$$
$$F = PA = \left(1.189\times10^5\ \mathrm{N/m^2}\right)\left(28.0\ \mathrm{m}\right)\left(8.5\ \mathrm{m}\right) = \boxed{2.8\times10^7\ \mathrm{N}}$$

(*b*) The pressure against the side of the pool, near the bottom, will be the same as the pressure at the bottom. Pressure is not directional. $P = \boxed{1.2\times10^5\ \mathrm{N/m^2}}$

18. (*a*) The mass of water in the tube is the volume of the tube times the density of water.

$$m = \rho V = \rho \pi r^2 h = \left(1.00\times10^3\ \mathrm{kg/m^3}\right)\pi\left(0.30\times10^{-2}\ \mathrm{m}\right)^2\left(12\ \mathrm{m}\right) = 0.3393\ \mathrm{kg} \approx \boxed{0.34\ \mathrm{kg}}$$

(*b*) The net force exerted on the lid is the gauge pressure of the water times the area of the lid. The gauge pressure is found from Eq. 13-3.

$$F = P_{\mathrm{gauge}} A = \rho g h \pi R^2 = \left(1.00\times10^3\ \mathrm{kg/m^3}\right)\left(9.80\ \mathrm{m/s^2}\right)\left(12\ \mathrm{m}\right)\pi\left(0.21\ \mathrm{m}\right)^2 = \boxed{1.6\times10^4\ \mathrm{N}}$$

$\boxed{19.}$ We use the relationship developed in Example 13-5.

$$P = P_0 e^{-(\rho_0 g/P_0)y} = \left(1.013\times10^5\ \mathrm{N/m^2}\right)e^{-\left(1.25\times10^{-4}\ \mathrm{m^{-1}}\right)\left(8850\ \mathrm{m}\right)} = \boxed{3.35\times10^4\ \mathrm{N/m^2}} \approx 0.331\ \mathrm{atm}$$

Note that if we used the constant density approximation, $P = P_0 + \rho g h$, a negative pressure would result.

26. If the iron is floating, then the net force on it is zero. The buoyant force on the iron must be equal to its weight. The buoyant force is equal to the weight of the mercury displaced by the submerged iron.

$$F_{\mathrm{buoyant}} = m_{\mathrm{Fe}} g \quad\rightarrow\quad \rho_{\mathrm{Hg}} g V_{\mathrm{submerged}} = \rho_{\mathrm{Fe}} g V_{\mathrm{total}} \quad\rightarrow$$
$$\frac{V_{\mathrm{submerged}}}{V_{\mathrm{total}}} = \frac{\rho_{\mathrm{Fe}}}{\rho_{\mathrm{Hg}}} = \frac{7.8\times10^3\ \mathrm{kg/m^3}}{13.6\times10^3\ \mathrm{kg/m^3}} = \boxed{0.57} \approx 57\%$$

35. The buoyant force on the ice is equal to the weight of the ice, since it floats.

$$F_{\mathrm{buoyant}} = W_{\mathrm{ice}} \quad\rightarrow\quad m_{\substack{\mathrm{seawater}\\ \mathrm{submerged}}}\, g = m_{\mathrm{ice}} g \quad\rightarrow\quad m_{\substack{\mathrm{seawater}\\ \mathrm{submerged}}} = m_{\mathrm{ice}} \quad\rightarrow$$
$$\rho_{\mathrm{seawater}} V_{\mathrm{seawater}} = \rho_{\mathrm{ice}} V_{\mathrm{ice}} \quad\rightarrow\quad \left(SG\right)_{\mathrm{seawater}} \rho_{\mathrm{water}} V_{\substack{\mathrm{submerged}\\ \mathrm{ice}}} = \left(SG\right)_{\mathrm{ice}} \rho_{\mathrm{water}} V_{\mathrm{ice}} \quad\rightarrow$$
$$\left(SG\right)_{\mathrm{seawater}} V_{\substack{\mathrm{submerged}\\ \mathrm{ice}}} = \left(SG\right)_{\mathrm{ice}} V_{\mathrm{ice}} \quad\rightarrow$$
$$V_{\substack{\mathrm{submerged}\\ \mathrm{ice}}} = \frac{\left(SG\right)_{\mathrm{ice}}}{\left(SG\right)_{\mathrm{seawater}}} V_{\mathrm{ice}} = \frac{0.917}{1.025} V_{\mathrm{ice}} = 0.895 V_{\mathrm{ice}}$$

Thus the fraction above the water is $V_{\text{above}} = V_{\text{ice}} - V_{\text{submerged}} = 0.105\ V_{\text{ice}}$ or $\boxed{10.5\%}$

36. (*a*) The difference in the actual mass and the apparent mass of the aluminum ball is the mass of the liquid displaced by the ball. The mass of the liquid displaced is the volume of the ball times the density of the liquid, and the volume of the ball is the mass of the ball divided by its density. Combining these relationships yields an expression for the density of the liquid.

$$m_{\text{actual}} - m_{\text{apparent}} = \Delta m = \rho_{\text{liquid}} V_{\text{ball}} = \rho_{\text{liquid}} \frac{m_{\text{ball}}}{\rho_{\text{Al}}} \rightarrow$$

$$\rho_{\text{liquid}} = \frac{\Delta m}{m_{\text{ball}}} \rho_{\text{Al}} = \frac{(3.80\,\text{kg} - 2.10\,\text{kg})}{3.80\,\text{kg}} \left(2.70 \times 10^3\,\text{kg/m}^3\right) = \boxed{1210\,\text{kg/m}^3}$$

(*b*) Generalizing the relation from above, we have $\boxed{\rho_{\text{liquid}} = \left(\dfrac{m_{\text{object}} - m_{\text{apparent}}}{m_{\text{object}}}\right) \rho_{\text{object}}}$.

39. The buoyant force must be equal to the combined weight of the helium balloons and the person. We ignore the buoyant force due to the volume of the person, and we ignore the mass of the balloon material.

$$F_{\text{B}} = \left(m_{\text{person}} + m_{\text{He}}\right) g \rightarrow \rho_{\text{air}} V_{\text{He}} g = \left(m_{\text{person}} + \rho_{\text{He}} V_{\text{He}}\right) g \rightarrow V_{\text{He}} = N \tfrac{4}{3} \pi r^3 = \frac{m_{\text{person}}}{\left(\rho_{\text{air}} - \rho_{\text{He}}\right)} \rightarrow$$

$$N = \frac{3 m_{\text{person}}}{4 \pi r^3 \left(\rho_{\text{air}} - \rho_{\text{He}}\right)} = \frac{3(75\,\text{kg})}{4\pi (0.165\,\text{m})^3 \left(1.29\,\text{kg/m}^3 - 0.179\,\text{kg/m}^3\right)} = 3587 \approx \boxed{3600\,\text{balloons}}$$

47. Apply Bernoulli's equation with point 1 being the water main, and point 2 being the top of the spray. The velocity of the water will be zero at both points. The pressure at point 2 will be atmospheric pressure. Measure heights from the level of point 1.

$$P_1 + \tfrac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2} \rho v_2^2 + \rho g y_2 \rightarrow$$

$$P_1 - P_{\text{atm}} = \rho g y_2 = \left(1.00 \times 10^3\,\text{kg/m}^3\right)\left(9.80\,\text{m/s}^2\right)(18\,\text{m}) = \boxed{1.8 \times 10^5\,\text{N/m}^2}$$

49. We assume that there is no appreciable height difference between the two sides of the roof. Then the net force on the roof due to the air is the difference in pressure on the two sides of the roof, times the area of the roof. The difference in pressure can be found from Bernoulli's equation.

$$P_{\text{inside}} + \tfrac{1}{2} \rho v_{\text{inside}}^2 + \rho g y_{\text{inside}} = P_{\text{outside}} + \tfrac{1}{2} \rho v_{\text{outside}}^2 + \rho g y_{\text{outside}} \rightarrow$$

$$P_{\text{inside}} - P_{\text{outside}} = \tfrac{1}{2}\rho_{\text{air}} v_{\text{outside}}^2 = \frac{F_{\text{air}}}{A_{\text{roof}}} \rightarrow$$

$$F_{\text{air}} = \tfrac{1}{2}\rho_{\text{air}} v_{\text{outside}}^2 A_{\text{roof}} = \tfrac{1}{2}\left(1.29\,\text{kg/m}^3\right)\left[\left(180\,\text{km/h}\right)\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right)\right]^2 \left(6.2\,\text{m}\right)\left(12.4\,\text{m}\right)$$

$$= \boxed{1.2\times 10^5\,\text{N}}$$

50. Use the equation of continuity (Eq. 13-7b) to relate the volume flow of water at the two locations, and use Bernoulli's equation (Eq. 13-8) to relate the pressure conditions at the two locations. We assume that the two locations are at the same height. Express the pressures as atmospheric pressure plus gauge pressure. Use subscript "1" for the larger diameter, and "2" for the smaller diameter.

$$A_1 v_1 = A_2 v_2 \rightarrow v_2 = v_1 \frac{A_1}{A_2} = v_1 \frac{\pi r_1^2}{\pi r_2^2} = v_1 \frac{r_1^2}{r_2^2}$$

$$P_0 + P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = P_0 + P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2 \rightarrow$$

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2 = P_2 + \tfrac{1}{2}\rho v_1^2 \frac{r_1^4}{r_2^4} \rightarrow v_1 = \sqrt{\frac{2\left(P_1 - P_2\right)}{\rho\left(\frac{r_1^4}{r_2^4} - 1\right)}} \rightarrow$$

$$A_1 v_1 = \pi r_1^2 \sqrt{\frac{2\left(P_1 - P_2\right)}{\rho\left(\frac{r_1^4}{r_2^4} - 1\right)}} = \pi\left(3.0\times 10^{-2}\,\text{m}\right)^2 \sqrt{\frac{2\left(32.0\times 10^3\,\text{Pa} - 24.0\times 10^3\,\text{Pa}\right)}{\left(1.0\times 10^3\,\text{kg/m}^3\right)\left(\frac{\left(3.0\times 10^{-2}\,\text{m}\right)^4}{\left(2.25\times 10^{-2}\,\text{m}\right)^4} - 1\right)}}$$

$$= \boxed{7.7\times 10^{-3}\,\text{m}^3/\text{s}}$$

52. The lift force would be the difference in pressure between the two wing surfaces, times the area of the wing surface. The difference in pressure can be found from Bernoulli's equation. We consider the two surfaces of the wing to be at the same height above the ground. Call the bottom surface of the wing point 1, and the top surface point 2.

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2 \rightarrow P_1 - P_2 = \tfrac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$F_{\text{lift}} = \left(P_1 - P_2\right)\left(\text{Area of wing}\right) = \tfrac{1}{2}\rho\left(v_2^2 - v_1^2\right)A$$

$$= \tfrac{1}{2}\left(1.29\,\text{kg/m}^3\right)\left[\left(280\,\text{m/s}\right)^2 - \left(150\,\text{m/s}\right)^2\right]\left(88\,\text{m}^2\right) = \boxed{3.2\times 10^6\,\text{N}}$$

95. Apply both Bernoulli's equation and the equation of continuity at the two locations of the stream,

with the faucet being location 0 and the lower position being location 1. The pressure will be air pressure at both locations. The lower location has $y_1 = 0$ and the faucet is at height $y_0 = y$.

$$A_0 v_0 = A_1 v_1 \quad \rightarrow \quad v_1 = v_0 \frac{A_0}{A_1} = v_0 \frac{\pi\left(d_0/2\right)^2}{\pi\left(d_1/2\right)^2} = v_0 \frac{d_0^2}{d_1^2} \quad \rightarrow$$

$$P_0 + \tfrac{1}{2}\rho v_0^2 + \rho g y_0 = P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 \quad \rightarrow \quad v_0^2 + 2gy = v_1^2 = v_0^2 \frac{d_0^4}{d_1^4} \quad \rightarrow$$

$$\boxed{d_1 = d_0 \left(\frac{v_0^2}{v_0^2 + 2gy} \right)^{1/4}}$$

CHAPTER 13: Fluids

Responses to Questions

4. The pressure is what determines whether or not your skin will be cut. You can push both the pen and the pin with the same force, but the pressure exerted by the point of the pin will be much greater than the pressure exerted by the blunt end of the pen, because the area of the pin point is much smaller.

7. Ice floats in water, so ice is less dense than water. When ice floats, it displaces a volume of water that is equal to the weight of the ice. Since ice is less dense than water, the volume of water displaced is smaller than the volume of the ice, and some of the ice extends above the top of the water. When the ice melts and turns back into water, it will fill a volume exactly equal to the original volume of water displaced. The water will not overflow the glass as the ice melts.

8. No. Alcohol is less dense than ice, so the ice cube would sink. In order to float, the ice cube would need to displace a weight of alcohol equal to its own weight. Since alcohol is less dense than ice, this is impossible.

9. All carbonated drinks have gas dissolved in them, which reduces their density to less than that of water. However, Coke has a significant amount of sugar dissolved in it, making its density greater than that of water, so the can of Coke sinks. Diet Coke has no sugar, leaving its density, including the can, less that the density of water. The can of Diet Coke floats.

17. The papers will move toward each other. When you blow between the sheets of paper, you reduce the air pressure between them (Bernoulli's principle). The greater air pressure on the other side of each sheet will push the sheets toward each other.

21. Taking off into the wind increases the velocity of the plane relative to the air, an important factor in the creation of lift. The plane will be able to take off with a slower ground speed, and a shorter runway distance.