Workshop week 8

13. ***REASONING*** Since the weight is distributed uniformly, each tire exerts one-half of the weight of the rider and bike on the ground. According to the definition of pressure, Equation 11.3, the force that each tire exerts on the ground is equal to the pressure P inside the tire times the area A of contact between the tire and the ground. From this relation, the area of contact can be found.

SOLUTION The area of contact that *each tire* makes with the ground is

$$A = \frac{F}{P} = \frac{\frac{1}{2}\left(W_{\text{person}} + W_{\text{bike}}\right)}{P} = \frac{\frac{1}{2}(625\text{ N} + 98\text{ N})}{7.60\times10^{5}\text{ Pa}} = \boxed{4.76\times10^{-4}\text{ m}^2} \qquad (11.3)$$

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14. ***REASONING*** According to Equation 11.3, the pressure P exerted on the ground by the stack of blocks is equal to the force F exerted by the blocks (their combined weight) divided by the area A of the block's surface in contact with the ground, or $P = F/A$. Since the pressure is largest when the area is smallest, the least number of blocks is used when the surface area in contact with the ground is the smallest. This area is $0.200\text{ m} \times 0.100\text{ m}$.

SOLUTION The pressure exerted by N blocks stacked on top of one another is

$$P = \frac{F}{A} = \frac{N W_{\text{one block}}}{A} \qquad (11.3)$$

where $W_{\text{one block}}$ is the weight of one block. The least number of whole blocks required to produce a pressure of two atmospheres (2.02×10^5 Pa) is

$$N = \frac{PA}{W_{\text{one block}}} = \frac{\left(2.02\times10^{5}\text{ Pa}\right)(0.200\text{ m}\times0.100\text{ m})}{169\text{ N}} = \boxed{24}$$

19. $\boxed{\text{SSM}}$ ***REASONING*** Since the faucet is closed, the water in the pipe may be treated as a static fluid. The gauge pressure P_2 at the faucet on the first floor is related to the gauge pressure P_1 at the faucet on the second floor by Equation 11.4, $P_2 = P_1 + \rho g h$.

SOLUTION

a. Solving Equation 11.4 for P_1, we find the gauge pressure at the second-floor faucet is

$$P_1 = P_2 - \rho g h = 1.90\times10^{5}\text{ Pa} - (1.00\times10^{3}\text{ kg/m}^3)(9.80\text{ m/s}^2)(6.50\text{ m}) = \boxed{1.26\times10^{5}\text{ Pa}}$$

b. If the second faucet were placed at a height h above the first-floor faucet so that the gauge pressure P_1 at the second faucet were zero, then no water would flow from the second faucet, even if it were open. Solving Equation 11.4 for h when P_1 equals zero, we obtain

$$h = \frac{P_2 - P_1}{\rho g} = \frac{1.90\times10^{5}\text{ Pa} - 0}{(1.00\times10^{3}\text{ kg/m}^3)(9.80\text{ m/s}^2)} = \boxed{19.4\text{ m}}$$

21. ***REASONING*** The magnitude of the force that would be exerted on the window is given by Equation 11.3, $F = PA$, where the pressure can be found from Equation 11.4: $P_2 = P_1 + \rho gh$. Since P_1 represents the pressure at the surface of the water, it is equal to atmospheric pressure, P_{atm}. Therefore, the magnitude of the force is given by

$$F = (P_{\text{atm}} + \rho gh)\,A$$

where, if we assume that the window is circular with radius r, its area A is given by $A = \pi r^2$.

SOLUTION
a. Thus, the magnitude of the force is

$$F = \left[1.013\times10^5 \text{ Pa} + (1025 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(11\ 000 \text{ m})\right]\pi(0.10 \text{ m})^2 = \boxed{3.5\times10^6 \text{ N}}$$

b. The weight of a jetliner whose mass is 1.2×10^5 kg is

$$W = mg = (1.2\times10^5 \text{ kg})(9.80 \text{ m/s}^2) = \boxed{1.2\times10^6 \text{ N}}$$

Therefore, the force exerted on the window at a depth of 11 000 m is about three times greater than the weight of a jetliner!

34. ***REASONING*** Equation 11.5 gives the force F_2 of the output plunger in terms of the force F_1 applied to the input piston as $F_2 = F_1(A_2/A_1)$, where A_2 and A_1 are the corresponding areas. In this problem the chair begins to rise when the output force just barely exceeds the weight, so $F_2 = 2100$ N. We are given the input force as 55 N. We seek the ratio of the radii, so we will express the area of each circular cross section as πr^2 when we apply Equation 11.5.

SOLUTION According to Equation 11.5, we have

$$\frac{A_2}{A_1} = \frac{F_2}{F_1} \quad \text{or} \quad \frac{\pi r_2^2}{\pi r_1^2} = \frac{F_2}{F_1}$$

Solving for the ratio of the radii yields

$$\frac{r_2}{r_1} = \sqrt{\frac{F_2}{F_1}} = \sqrt{\frac{2100 \text{ N}}{55 \text{ N}}} = \boxed{6.2}$$

38. ***REASONING*** Since the duck is in equilibrium, its downward-acting weight is balanced by the upward-acting buoyant force. According to Archimedes' principle, the magnitude of the buoyant force is equal to the weight of the water displaced by the duck. Setting the weight of the duck equal to the magnitude of the buoyant force will allow us to find the average density of the duck.

SOLUTION Since the weight W_{duck} of the duck is balanced by the magnitude F_B of the buoyant force, we have that $W_{\text{duck}} = F_B$. The duck's weight is $W_{\text{duck}} = mg = (\rho_{\text{duck}} V_{\text{duck}})g$, where ρ_{duck} is the average density of the duck and V_{duck} is its volume. The magnitude of the buoyant force, on the other hand, equals the weight of the water displaced by the duck, or $F_B = m_{\text{water}} g$, where m_{water} is the mass of the displaced water. But $m_{\text{water}} = \rho_{\text{water}}\left(\frac{1}{4} V_{\text{duck}}\right)$, since one-quarter of the duck's volume is beneath the water. Thus,

$$\underbrace{\rho_{\text{duck}} V_{\text{duck}}\, g}_{\text{Weight of duck}} = \underbrace{\rho_{\text{water}}\left(\tfrac{1}{4} V_{\text{duck}}\right) g}_{\substack{\text{Magnitude of} \\ \text{buoyant force}}}$$

Solving this equation for the average density of the duck (and taking the density of water from Table 11.1) gives

$$\rho_{\text{duck}} = \tfrac{1}{4}\rho_{\text{water}} = \tfrac{1}{4}\left(1.00 \times 10^3 \text{ kg/m}^3\right) = \boxed{250 \text{ kg/m}^3}$$

40. ***REASONING*** The ice with the bear on it is floating, so that the upward-acting buoyant force balances the downward-acting weight W_{ice} of the ice and weight W_{bear} of the bear. The magnitude F_B of the buoyant force is the weight W_{H_2O} of the displaced water, according to Archimedes' principle. Thus, we have $F_B = W_{H_2O} = W_{\text{ice}} + W_{\text{bear}}$, the expression with which we will obtain W_{bear}. We can express each of the weights W_{H_2O} and

W_{ice} as mass times the magnitude of the acceleration due to gravity (Equation 4.5) and then relate the mass to the density and the displaced volume by using Equation 11.1.

SOLUTION Since the ice with the bear on it is floating, the upward-acting buoyant force F_B balances the downward-acting weight W_{ice} of the ice and the weight W_{bear} of the bear. The buoyant force has a magnitude that equals the weight W_{H_2O} of the displaced water, as stated by Archimedes' principle. Thus, we have

$$F_B = W_{H_2O} = W_{ice} + W_{bear} \quad \text{or} \quad W_{bear} = W_{H_2O} - W_{ice} \tag{1}$$

In Equation (1), we can use Equation 4.5 to express the weights W_{H_2O} and W_{ice} as mass m times the magnitude g of the acceleration due to gravity. Then, the each mass can be expressed as $m = \rho V$ (Equation 11.1). With these substitutions, Equation (1) becomes

$$W_{bear} = m_{H_2O}g - m_{ice}g = (\rho_{H_2O}V_{H_2O})g - (\rho_{ice}V_{ice})g \tag{2}$$

When the heaviest possible bear is on the ice, the ice is just below the water surface and displaces a volume of water that is $V_{H_2O} = V_{ice}$. Substituting this result into Equation (2), we find that

$$W_{bear} = (\rho_{H_2O}V_{ice})g - (\rho_{ice}V_{ice})g = (\rho_{H_2O} - \rho_{ice})V_{ice}g$$

$$= \left(1025 \text{ kg/m}^3 - 917 \text{ kg/m}^3\right)\left(5.2 \text{ m}^3\right)\left(9.80 \text{ m/s}^2\right) = \boxed{5500 \text{ N}}$$