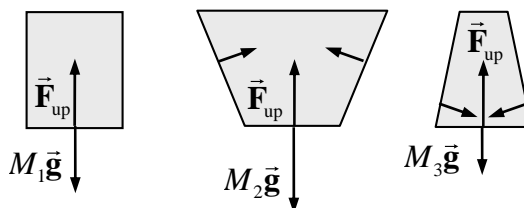


## CHAPTER 10: Fluids

### Answers to Questions

1. Density is the ratio of mass to volume. A high density may mean that lighter molecules are packed more closely together and thus a given amount of mass is occupying a smaller volume, making a higher density. An atom of gold weighs less than an atom of lead, because gold has a lower atomic mass, but the density of gold is higher than that of lead.
2. The air pressure inside the cabin of an airplane is lower than normal sea-level air pressure, evidenced by the sensation in the ears as the plane descends and the cabin reaches normal air pressure. If the container was opened at normal air pressure before the flight, then the pressure inside the container is normal air pressure. During the flight, while the pressure outside the container is lower than that inside the container, the difference in pressure causes a force from the inside towards the outside, and so the contents may get forced out of the container.
3. Let the first container have a mass of water  $M_1$ . The force of gravity on the water, acting downward, is thus  $M_1g$ . The side walls only exert a force perpendicular to the walls, which is horizontal for the first container. Thus there must also be a net upward force of  $F_{\text{up}} = M_1g$  on the water to keep it at rest. This is the normal force from the bottom of the container. This upward force is the pressure at the bottom of the container times the area of the container, and is the same for all three containers. The second container has more water, and so has a larger downward force of gravity on it ( $M_2g > F_{\text{up}}$ ), but the same upward force from the bottom of the container. Thus there must be additional upward force on the water. That upward force comes from the normal force of the slanted sides of the container pushing on the water. That force has an upward component – just enough to add to the normal force and balance the force of gravity. Similarly, the third container has less water, and so has a smaller downward force of gravity ( $M_3g < F_{\text{up}}$ ). With the same upward normal force from the bottom, there must be more downward force on the water for it to be at rest. That downward force comes from the normal force of the slanted sides of the container pushing on the water. That force has a downward component – just enough to add to the gravity force and balance the force. The key to this problem is that the force on a container due to the hydrostatic pressure is always perpendicular to the surface of the water. According to Newton's 3<sup>rd</sup> law, the container will push back on the water in the exact opposite direction, also perpendicular to the surface of the container.



4. The sharp end of the pin (with a smaller area) will pierce the skin when pushed with a certain minimum force, while the same force applied in pushing the blunt end of the pen (with a larger area) into the skin does not pierce the skin. Thus it is pressure (force per unit area) that determines whether or not the skin is pierced.

5. The boiling water makes a relatively large quantity of steam inside the can. The gas inside the can (including the steam) will be at atmospheric pressure, but will be much warmer than the surroundings. When the gas in the sealed can cools, the steam condenses and the pressure drops greatly. This lowering of pressure on the inside means that the outside air pressure is higher than the pressure in the can, and thus the outside air pressure crushes the can.

From a microscopic viewpoint, the water molecules are moving very fast when boiled to a vapor. Many of the water molecules escape the can, but the remaining ones can hold the can in its original shape because their high speeds mean they hit the walls with a large force and balance the force caused by the outside air pressure. After the lid is put on and the can is cooled, the water vapor molecules slow down (some will condense), and no gas can enter from outside the can. The slow molecules are not moving as fast and so put less force on the inside walls. The greater force from the outside air pressure then crushes the can.

6. The blood pressure exerted by the heart is to be measured. If the blood pressure is measured at a location  $h$  lower than the heart, the blood pressure will be higher than the pressure at the heart, due to the effects of gravity, by an amount  $\rho gh$ . Likewise, if the blood pressure is measured at a location  $h$  higher than the heart, the blood pressure will be lower than the pressure at the heart, again due to the effects of gravity, by an amount  $\rho gh$ .
7. Since the ice floats, the density of ice must be less than that of the water. The mass of the ice displaces a water volume equal to its weight, whether it is solid or liquid. Thus as the ice melts, the level in the glass stays the same. The ice displaces its melted volume.
8. The density of ice is greater than that of alcohol, so the ice cube will not float in a glass of alcohol. The ice cube will sink in the alcohol.
9. Both products have gas dissolved in them (the carbonation process), making their density lower than that of water. The Coke has a significant amount of sugar dissolved in it, increasing its density and making it greater than that of water. The Diet Coke does not have the dissolved sugar, and so its density remains less than that of water. Thus the Coke sinks, and the Diet Coke floats.
10. Iron ships are not solid iron. If they were, then they would sink. But the ships have quite a bit of open space in their volume (the volume between the deck and the hull, for instance), making their overall density less than that of water. The total mass of iron divided by the total volume of the boat is less than the density of water, and so the boat floats.
11. Refer to the diagram in the textbook. The pressure at the surface of both containers of liquid is atmospheric pressure. The pressure in each tube would thus be atmospheric pressure at the level of the surface of the liquid in each container. The pressure in each tube will decrease with height by an amount  $\rho gh$ . Since the portion of the tube going into the lower container is longer than the portion of the tube going into the higher container, the pressure at the highest point on the right side is lower than the pressure at the highest point on the left side. This pressure difference causes liquid to flow from the left side of the tube to the right side of the tube. And as noted in the question, the tube must be filled with liquid before this argument can be made.
12. Since sand is denser than water, adding a given volume of sand (equal to the area of the barge times the depth of added sand) to the barge will require that an even greater volume of water be displaced to support the added weight. Thus the extra height of the barge caused by adding the sand will be more than compensated for by the extra depth to which the barge has to be submerged in order to float. Removing sand would have the opposite effect – the barge would get higher.

13. If you assume that the air is incompressible, then the answer is yes. The full balloon will have more weight (more downward force), due to the mass of the air in the balloon. The full balloon will also have an upward buoyant force on it, equal to the weight of the air displaced by the balloon. Since the balloon is both containing air and floating in air, the weight of the air inside the balloon is the same magnitude as the buoyant force. Thus the empty balloon will have the same apparent weight as the filled balloon.

However, the air inside the balloon is compressed slightly compared to the outside air, and so has a higher density. This higher density means that the weight of the air inside the balloon is higher than the weight of the air it displaces, and so the filled balloon has a higher apparent weight than the empty balloon.

14. As the balloon rises, the air pressure outside the balloon will decrease and be lower than the pressure inside the balloon. The excess inside air pressure will cause the balloon to expand, lowering the pressure inside but stretching the balloon in the process. If, at launch, the material of the balloon were already stretched to the limit, the expansion of the balloon due to the decreasing outside air pressure would cause the balloon to burst. Thus the balloon is only filled to a fraction of the maximum volume.
15. (a) The boat displaces enough water to equal the weight of the boat. If the boat is removed from the water, the water will no longer be displaced and thus the water level will lower.  
(b) While the anchor is in the boat, the water displaced has a weight equal to that of the boat and the anchor together. If the anchor is placed on the shore, then less water will need to be displaced, and the water level will lower.  
(c) While the anchor is in the boat, the water displaced has a weight equal to that of the boat and the anchor together. If the anchor is dropped into the pool, the water displaced is equal to the weight of the boat (which will float) and the weight of a volume of water equal to the volume of the anchor (which will sink). Since the anchor is more dense than the water, it takes more water displacement to hold up the anchor (while in the boat) than is displaced when the anchor is in the water. Thus the water level will lower when the anchor is thrown overboard.
16. Salt water has a higher density than fresh water. Thus you have to displace less salt water to equal your weight than you do in fresh water. You then float “higher” in the salt water.
17. The papers will move toward each other. Bernoulli’s principle says that as the speed of the gas flow increases, the pressure decreases (when there is no appreciable change in height). So as the air passes between the papers, the air pressure between the papers is lowered. The air pressure on the outside of the papers is then greater than that between the papers, and so the papers are pushed together.
18. As the car drives through the air, the air inside the car is stationary with respect to the top, but the outside air is moving with respect to the top. There is no appreciable change in height between the two sides of the canvas top. By Bernoulli’s principle, the outside air pressure near the canvas top will be less than the inside air pressure. That difference in pressure results in a force that makes the top bulge outward.
19. The roofs are actually pushed off from the inside. By Bernoulli’s principle, the fast moving winds of the tornado or hurricane cause the air pressure above the roof to be quite low, but the pressure inside the house is still near normal levels. There is no appreciable change in height between the two sides of the roof. This pressure difference, combined with the large surface area of the roof, gives a very large force which can push the roof off the house. That is why it is advised to open some windows if

a tornado is imminent, so that the pressure inside the house can somewhat equalize with the outside pressure.

20. It is possible. Due to viscosity, some of the air near the train will be pulled along at a speed approximately that of the train. By Bernoulli's principle, that air will be at a lower pressure than air further away from the train. That difference in pressure results in a force towards the train, which could push a lightweight child towards the train.
21. Water will not flow from the holes when the cup and water are in free fall. The acceleration due to gravity is the same for all falling objects (ignoring friction), and so the cup and water would fall together. For the water to flow out of the holes while falling would mean that the water would have an acceleration larger than the acceleration due to gravity. Another way to consider the situation is that there will no longer be a pressure difference between the top and bottom of the cup of water, since the lower water molecules don't need to hold up the upper water molecules.
22. The lift generated by a wind depends on the speed of the air relative to the wing. For example, a model in a wind tunnel will have lift even though the model isn't moving relative to the ground. By taking off into the wind, the speed of the air relative to the wing is the sum of the plane's speed and the wind speed. This allows the plane to take off at a lower ground speed, requiring a shorter runway.
23. As the stream of water falls, its vertical speed is faster away from the faucet than close to it, due to the acceleration caused by gravity. Since the water is essentially incompressible, Eq. 10-4b applies, which says that a faster flow has a smaller cross-sectional area. Thus the faster moving water has a narrower stream.
24. When the two ships are moving parallel to each other, water between them starts to move with them due to viscosity. There will be more water moving along with the ships in between them than on their outside sides. According to Bernoulli's principle, this moving water is at a lower pressure than stationary water, further away from the ship. Each ship will thus experience a net force towards the other ship and be drawn in towards the other ship. Thus they risk colliding.

## Solutions to Problems

1. The mass is found from the density of granite and the volume of granite.

$$m = \rho V = (2.7 \times 10^3 \text{ kg/m}^3)(10^8 \text{ m}^3) = 2.7 \times 10^{11} \text{ kg} \approx \boxed{3 \times 10^{11} \text{ kg}}$$

2. The mass is found from the density of air and the volume of air.

$$m = \rho V = (1.29 \text{ kg/m}^3)(4.8 \text{ m})(3.8 \text{ m})(2.8 \text{ m}) = \boxed{66 \text{ kg}}$$

3. The mass is found from the density of gold and the volume of gold.

$$m = \rho V = (19.3 \times 10^3 \text{ kg/m}^3)(0.60 \text{ m})(0.28 \text{ m})(0.18 \text{ m}) = \boxed{5.8 \times 10^2 \text{ kg}} \quad (\sim 1300 \text{ lb})$$

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

$$V = \frac{m}{\rho} = \frac{75 \text{ kg}}{1.00 \times 10^3 \text{ kg/m}^3} = \boxed{7.5 \times 10^{-2} \text{ m}^3} = 75 \text{ L}$$

5. To find the specific gravity of the fluid, take the ratio of the density of the fluid to that of water, noting that the same volume is used for both liquids.

$$SG_{\text{fluid}} = \frac{\rho_{\text{fluid}}}{\rho_{\text{water}}} = \frac{(m/V)_{\text{fluid}}}{(m/V)_{\text{water}}} = \frac{m_{\text{fluid}}}{m_{\text{water}}} = \frac{88.78 \text{ g} - 35.00 \text{ g}}{98.44 \text{ g} - 35.00 \text{ g}} = \boxed{0.8477}$$

6. The specific gravity of the mixture is the ratio of the density of the mixture to that of water. To find the density of the mixture, the mass of antifreeze and the mass of water must be known.

$$\begin{aligned} m_{\text{antifreeze}} &= \rho_{\text{antifreeze}} V_{\text{antifreeze}} = SG_{\text{antifreeze}} \rho_{\text{water}} V_{\text{antifreeze}} & m_{\text{water}} &= \rho_{\text{water}} V_{\text{water}} \\ SG_{\text{mixture}} &= \frac{\rho_{\text{mixture}}}{\rho_{\text{water}}} = \frac{m_{\text{mixture}}/V_{\text{mixture}}}{\rho_{\text{water}}} = \frac{m_{\text{antifreeze}} + m_{\text{water}}}{\rho_{\text{water}} V_{\text{mixture}}} = \frac{SG_{\text{antifreeze}} \rho_{\text{water}} V_{\text{antifreeze}} + \rho_{\text{water}} V_{\text{water}}}{\rho_{\text{water}} V_{\text{mixture}}} \\ &= \frac{SG_{\text{antifreeze}} V_{\text{antifreeze}} + V_{\text{water}}}{V_{\text{mixture}}} = \frac{(0.80)(5.0 \text{ L}) + 4.0 \text{ L}}{9.0 \text{ L}} = \boxed{0.89} \end{aligned}$$

7. (a) The pressure exerted on the floor by the chair leg is caused by the leg 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 is equal to the weight of the leg. Thus the pressure is

$$P_{\text{chair}} = \frac{W_{\text{leg}}}{A} = \frac{\frac{1}{4}(60 \text{ kg})(9.8 \text{ m/s}^2)}{(0.020 \text{ cm}^2) \left( \frac{1 \text{ m}}{100 \text{ cm}} \right)^2} = 7.35 \times 10^7 \text{ N/m}^2 \approx \boxed{7 \times 10^7 \text{ N/m}^2}.$$

- (b) The pressure exerted by the elephant is

$$P_{\text{elephant}} = \frac{W_{\text{elephant}}}{A} = \frac{(1500 \text{ kg})(9.8 \text{ m/s}^2)}{(800 \text{ cm}^2) \left( \frac{1 \text{ m}}{100 \text{ cm}} \right)^2} = 1.84 \times 10^5 \text{ N/m}^2 \approx \boxed{2 \times 10^5 \text{ N/m}^2}.$$

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

8. From Equation 10-3b, the pressure difference is

$$\begin{aligned} \Delta P &= \rho g \Delta h = (1.05 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(1.60 \text{ m}) = 1.646 \times 10^4 \text{ N/m}^2 \left( \frac{1 \text{ mm-Hg}}{133 \text{ N/m}^2} \right) \\ &= \boxed{124 \text{ mm-Hg}} \end{aligned}$$

9. (a) The total force of the atmosphere on the table will be the air pressure times the area of the table.

$$F = PA = (1.013 \times 10^5 \text{ N/m}^2)(1.6 \text{ m})(2.9 \text{ m}) = \boxed{4.7 \times 10^5 \text{ N}}$$

- (b) Since the atmospheric pressure is the same on the underside of the table (the height difference is minimal), the upward force of air pressure is the same as the downward force of air on the top of the table,  $\boxed{4.7 \times 10^5 \text{ N}}$ .

10. The pressure difference on the lungs is the pressure change from the depth of water

$$\Delta P = \rho g \Delta h \rightarrow \Delta h = \frac{\Delta P}{\rho g} = \frac{(85 \text{ mm-Hg}) \left( \frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}} \right)}{(1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = 1.154 \text{ m} \approx \boxed{1.2 \text{ m}}$$

11. The sum of the force exerted by the pressure in each tire is equal to the weight of the car.

$$mg = 4PA \rightarrow m = \frac{4PA}{g} = \frac{4(2.40 \times 10^5 \text{ N/m}^2)(220 \text{ cm}^2)\left(\frac{1 \text{ m}^2}{10^4 \text{ cm}^2}\right)}{(9.80 \text{ m/s}^2)} = \boxed{2.2 \times 10^3 \text{ kg}}$$

12. The force exerted by the gauge pressure will be equal to the weight of the vehicle.

$$mg = PA = P(\pi r^2) \rightarrow$$

$$m = \frac{P\pi r^2}{g} = \frac{\pi(17.0 \text{ atm})\left(\frac{1.013 \times 10^5 \text{ N/m}^2}{1 \text{ atm}}\right)(0.140 \text{ m})^2}{(9.80 \text{ m/s}^2)} = \boxed{1.08 \times 10^4 \text{ kg}}$$

13. The height is found from Eq. 10-3a, using normal atmospheric pressure.

$$P = \rho gh \rightarrow h = \frac{P}{\rho g} = \frac{1.013 \times 10^5 \text{ N/m}^2}{(0.79 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = \boxed{13 \text{ m}}$$

14. (a) The absolute pressure is given by Eq. 10-3c, and the total force is the absolute pressure times the area of the bottom of the pool.

$$P = P_0 + \rho gh = 1.013 \times 10^5 \text{ N/m}^2 + (1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(2.0 \text{ m})$$

$$= \boxed{1.21 \times 10^5 \text{ N/m}^2}$$

$$F = PA = (1.21 \times 10^5 \text{ N/m}^2)(22.0 \text{ m})(8.5 \text{ m}) = \boxed{2.3 \times 10^7 \text{ N}}$$

- (b) The pressure against the side of the pool, near the bottom, will be the same as the pressure at the bottom,  $P = \boxed{1.21 \times 10^5 \text{ N/m}^2}$

15. If the atmosphere were of uniform density, then the pressure at any height  $h$  would be  $P = P_0 - \rho gh$ . At the top of the uniform atmosphere, the pressure would be 0. Thus solve for the height at which the pressure becomes 0, using a density of half of sea-level atmospheric density.

$$P = P_0 - \rho gh = 0 \rightarrow h = \frac{P_0}{\rho g} = \frac{(1.013 \times 10^5 \text{ N/m}^2)}{\frac{1}{2}(1.29 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = \boxed{1.60 \times 10^4 \text{ m}}$$

16. The pressure at points a and b are equal since they are the same height in the same fluid. If they were unequal, the fluid would flow. Calculate the pressure at both a and b, starting with atmospheric pressure at the top surface of each liquid, and then equate those pressures.

$$P_a = P_b \rightarrow P_0 + \rho_{\text{oil}}gh_{\text{oil}} = P_0 + \rho_{\text{water}}gh_{\text{water}} \rightarrow \rho_{\text{oil}}h_{\text{oil}} = \rho_{\text{water}}h_{\text{water}} \rightarrow$$

$$\rho_{\text{oil}} = \frac{\rho_{\text{water}}h_{\text{water}}}{h_{\text{oil}}} = \frac{(1.00 \times 10^3 \text{ kg/m}^3)(0.272 \text{ m} - 0.0941 \text{ m})}{(0.272 \text{ m})} = \boxed{6.54 \times 10^2 \text{ kg/m}^3}$$

17. (a) The gauge pressure is given by Eq. 10-3a. The height is the height from the bottom of the hill to the top of the water tank.

$$P_G = \rho gh = (1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)[5.0 \text{ m} + (110 \text{ m})\sin 58^\circ] = \boxed{9.6 \times 10^5 \text{ N/m}^2}$$

- (b) The water would be able to shoot up to the top of the tank (ignoring any friction).

$$h = 5.0 \text{ m} + (110 \text{ m}) \sin 58^\circ = \boxed{98 \text{ m}}$$

18. The minimum gauge pressure would cause the water to come out of the faucet with very little speed. This means the gauge pressure needed must be enough to hold the water at this elevation. Use Eq. 10-3a.

$$P_G = \rho gh = (1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(38 \text{ m}) = \boxed{3.7 \times 10^5 \text{ N/m}^2}$$

19. The pressure in the tank is atmospheric pressure plus the pressure difference due to the column of mercury, as given in Eq. 10-3c.

$$(a) \quad P = P_0 + \rho gh = 1.04 \text{ bar} + \rho_{\text{Hg}} gh$$

$$= (1.04 \text{ bar}) \left( \frac{1.00 \times 10^5 \text{ N/m}^2}{1 \text{ bar}} \right) + (13.6 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(0.280 \text{ m}) = \boxed{1.41 \times 10^5 \text{ N/m}^2}$$

$$(b) \quad P = (1.04 \text{ bar}) \left( \frac{1.00 \times 10^5 \text{ N/m}^2}{1 \text{ bar}} \right) + (13.6 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(-0.042 \text{ m}) = \boxed{9.84 \times 10^4 \text{ N/m}^2}$$

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

$$m = \rho V = \rho \pi r^2 h = (1.00 \times 10^3 \text{ kg/m}^3) \pi (0.30 \times 10^{-2} \text{ m})^2 (12 \text{ m}) = 0.3393 \text{ kg} \approx \boxed{0.34 \text{ kg}}$$

- (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. 10-3b.

$$F = P_{\text{gauge}} A = \rho gh \pi R^2 = (1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(12 \text{ m}) \pi (0.21 \text{ m})^2 = \boxed{1.6 \times 10^4 \text{ N}}$$

21. From section 9-5, the change in volume due to pressure change is  $\frac{\Delta V}{V_0} = -\frac{\Delta P}{B}$ , where  $B$  is the bulk

modulus of the water, given in Table 9-1. The pressure increase with depth for a fluid of constant density is given by  $\Delta P = \rho g \Delta h$ , where  $\Delta h$  is the depth of descent. If the density change is small, then we can use the initial value of the density to calculate the pressure change, and so  $\Delta P \cong \rho_0 g \Delta h$ . Finally, consider a constant mass of water. That constant mass will relate the volume and density at the two locations by  $M = \rho V = \rho_0 V_0$ . Combine these relationships and solve for the density deep in the sea,  $\rho$ .

$$\rho V = \rho_0 V_0 \rightarrow$$

$$\rho = \frac{\rho_0 V_0}{V} = \frac{\rho_0 V_0}{V_0 + \Delta V} = \frac{\rho_0 V_0}{V_0 + \left( -V_0 \frac{\Delta P}{B} \right)} = \frac{\rho_0}{1 - \frac{\rho_0 g h}{B}} = \frac{1025 \text{ kg/m}^3}{1 - \frac{(1025 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(6.0 \times 10^3 \text{ m})}{2.0 \times 10^9 \text{ N/m}^2}}$$

$$= 1057 \text{ kg/m}^3 \approx \boxed{1.06 \times 10^3 \text{ kg/m}^3}$$

$$\rho / \rho_0 = \frac{1057}{1025} = 1.03$$

The density at the 6 km depth is about  $\boxed{3\% \text{ larger}}$  than the density at the surface.

22. The difference in the actual mass and the apparent mass is the mass of the water displaced by the rock. The mass of the water displaced is the volume of the rock times the density of water, and the volume of the rock is the mass of the rock divided by its density. Combining these relationships yields an expression for the density of the rock.

$$m_{\text{actual}} - m_{\text{apparent}} = \Delta m = \rho_{\text{water}} V_{\text{rock}} = \rho_{\text{water}} \frac{m_{\text{rock}}}{\rho_{\text{rock}}} \rightarrow$$

$$\rho_{\text{rock}} = \rho_{\text{water}} \frac{m_{\text{rock}}}{\Delta m} = (1.00 \times 10^3 \text{ kg/m}^3) \frac{9.28 \text{ kg}}{9.28 \text{ kg} - 6.18 \text{ kg}} = \boxed{2.99 \times 10^3 \text{ kg/m}^3}$$

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

$$F_{\text{buoyant}} = m_{\text{Al}} g \rightarrow \rho_{\text{Hg}} g V_{\text{submerged}} = \rho_{\text{Al}} g V_{\text{total}} \rightarrow$$

$$\frac{V_{\text{submerged}}}{V_{\text{total}}} = \frac{\rho_{\text{Al}}}{\rho_{\text{Hg}}} = \frac{2.70 \times 10^3 \text{ kg/m}^3}{13.6 \times 10^3 \text{ kg/m}^3} = \boxed{0.199} \approx 20\%$$

24. (a) When the hull is submerged, both the buoyant force and the tension force act upward on the hull, and so their sum is equal to the weight of the hull. The buoyant force is the weight of the water displaced.

$$T + F_{\text{buoyant}} = mg \rightarrow$$

$$T = mg - F_{\text{buoyant}} = m_{\text{hull}} g - \rho_{\text{water}} V_{\text{sub}} g = m_{\text{hull}} g - \rho_{\text{water}} \frac{m_{\text{hull}}}{\rho_{\text{hull}}} g = m_{\text{hull}} g \left( 1 - \frac{\rho_{\text{water}}}{\rho_{\text{hull}}} \right)$$

$$= (1.8 \times 10^4 \text{ kg})(9.80 \text{ m/s}^2) \left( 1 - \frac{1.00 \times 10^3 \text{ kg/m}^3}{7.8 \times 10^3 \text{ kg/m}^3} \right) = 1.538 \times 10^5 \text{ N} \approx \boxed{1.5 \times 10^5 \text{ N}}$$

- (b) When the hull is completely out of the water, the tension in the crane's cable must be equal to the weight of the hull.

$$T = mg = (1.8 \times 10^4 \text{ kg})(9.80 \text{ m/s}^2) = 1.764 \times 10^5 \text{ N} \approx \boxed{1.8 \times 10^5 \text{ N}}$$

25. The buoyant force of the balloon must equal the weight of the balloon plus the weight of the helium in the balloon plus the weight of the load. For calculating the weight of the helium, we assume it is at 0°C and 1 atm pressure. The buoyant force is the weight of the air displaced by the volume of the balloon.

$$F_{\text{buoyant}} = \rho_{\text{air}} V_{\text{balloon}} g = m_{\text{He}} g + m_{\text{balloon}} g + m_{\text{cargo}} g \rightarrow$$

$$m_{\text{cargo}} = \rho_{\text{air}} V_{\text{balloon}} - m_{\text{He}} - m_{\text{balloon}} = \rho_{\text{air}} V_{\text{balloon}} - \rho_{\text{He}} V_{\text{balloon}} - m_{\text{balloon}} = (\rho_{\text{air}} - \rho_{\text{He}}) V_{\text{balloon}} - m_{\text{balloon}}$$

$$= (1.29 \text{ kg/m}^3 - 0.179 \text{ kg/m}^3) \frac{4}{3} \pi (7.35 \text{ m})^3 - 930 \text{ kg} = \boxed{920 \text{ kg}} = 9.0 \times 10^3 \text{ N}$$

26. The difference in the actual mass and the apparent mass is the mass of the water displaced by the legs. The mass of the water displaced is the volume of the legs times the density of water, and the volume of the legs is the mass of the legs divided by their density. The density of the legs is assumed to be the same as that of water. Combining these relationships yields an expression for the mass of the legs.



$$m_{\text{actual}} - m_{\text{apparent}} = \Delta m = \rho_{\text{water}} V_{\text{legs}} = \rho_{\text{water}} \frac{m_{\text{legs}}}{\rho_{\text{legs}}} = 2m_{\text{leg}} \rightarrow$$

$$m_{\text{leg}} = \frac{\Delta m}{2} = \frac{(78 \text{ kg} - 54 \text{ kg})}{2} = \boxed{12 \text{ kg}}$$

27. The apparent weight is the actual weight minus the buoyant force. The buoyant force is weight of a mass of water occupying the volume of the metal sample.

$$m_{\text{apparent}} g = m_{\text{metal}} g - F_{\text{B}} = m_{\text{metal}} g - V_{\text{metal}} \rho_{\text{H}_2\text{O}} g = m_{\text{metal}} g - \frac{m_{\text{metal}}}{\rho_{\text{metal}}} \rho_{\text{H}_2\text{O}} g \rightarrow$$

$$m_{\text{apparent}} = m_{\text{metal}} - \frac{m_{\text{metal}}}{\rho_{\text{metal}}} \rho_{\text{H}_2\text{O}} \rightarrow$$

$$\rho_{\text{metal}} = \frac{m_{\text{metal}}}{(m_{\text{metal}} - m_{\text{apparent}})} \rho_{\text{H}_2\text{O}} = \frac{63.5 \text{ g}}{(63.5 \text{ g} - 55.4 \text{ g})} (1000 \text{ kg/m}^3) = 7840 \text{ kg/m}^3$$

Based on the density value, the metal is probably iron or steel.

28. The difference in the actual mass and the apparent mass of the aluminum is the mass of the air displaced by the aluminum. The mass of the air displaced is the volume of the aluminum times the density of air, and the volume of the aluminum is the actual mass of the aluminum divided by the density of aluminum. Combining these relationships yields an expression for the actual mass.

$$m_{\text{actual}} - m_{\text{apparent}} = \rho_{\text{air}} V_{\text{Al}} = \rho_{\text{air}} \frac{m_{\text{actual}}}{\rho_{\text{Al}}} \rightarrow$$

$$m_{\text{actual}} = \frac{m_{\text{apparent}}}{1 - \frac{\rho_{\text{air}}}{\rho_{\text{Al}}}} = \frac{2.0000 \text{ kg}}{1 - \frac{1.29 \text{ kg/m}^3}{2.70 \times 10^3 \text{ kg/m}^3}} = \boxed{2.0010 \text{ kg}}$$

29. There are three forces on the chamber: the weight of the chamber, the tension in the cable, and the buoyant force. See the free-body diagram.

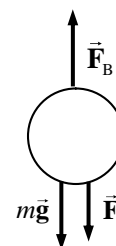
(a) The buoyant force is the weight of water displaced by the chamber.

$$\begin{aligned} F_{\text{buoyant}} &= \rho_{\text{H}_2\text{O}} V_{\text{chamber}} g = \rho_{\text{H}_2\text{O}} \frac{4}{3} \pi R_{\text{chamber}}^3 g \\ &= (1.025 \times 10^3 \text{ kg/m}^3) \frac{4}{3} \pi (2.60 \text{ m})^3 (9.80 \text{ m/s}^2) \\ &= 7.3953 \times 10^5 \text{ N} \approx \boxed{7.40 \times 10^5 \text{ N}} \end{aligned}$$

(b) To find the tension, use Newton's 2<sup>nd</sup> law for the stationary chamber.

$$F_{\text{buoyant}} = mg + F_{\text{T}} \rightarrow$$

$$F_{\text{T}} = F_{\text{buoyant}} - mg = 7.3953 \times 10^5 \text{ N} - (7.44 \times 10^4 \text{ kg})(9.80 \text{ m/s}^2) = \boxed{1.04 \times 10^4 \text{ N}}$$



30. (a) The buoyant force is the weight of the water displaced, using the density of sea water.

$$\begin{aligned} F_{\text{buoyant}} &= m_{\text{water displaced}} g = \rho_{\text{water}} V_{\text{displaced}} g \\ &= (1.025 \times 10^3 \text{ kg/m}^3) (65.0 \text{ L}) \left( \frac{1 \times 10^{-3} \text{ m}^3}{1 \text{ L}} \right) (9.80 \text{ m/s}^2) = \boxed{653 \text{ N}} \end{aligned}$$

(b) The weight of the diver is  $m_{\text{diver}} g = (68.0 \text{ kg})(9.80 \text{ m/s}^2) = 666 \text{ N}$ . Since the buoyant force is not as large as her weight, **she will sink**, although it will be very gradual since the two forces are almost the same.

31. (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.

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

$$\rho_{\text{liquid}} = \frac{\Delta m}{m_{\text{ball}}} \rho_{\text{Al}} = \frac{(3.40 \text{ kg} - 2.10 \text{ kg})}{3.40 \text{ kg}} (2.70 \times 10^3 \text{ kg/m}^3) = \boxed{1.03 \times 10^3 \text{ kg/m}^3}$$

(b) Generalizing the relation from above, we have  $\rho_{\text{liquid}} = \frac{m_{\text{object}} - m_{\text{apparent}}}{m_{\text{object}}} \rho_{\text{object}}$

32. The difference in the actual mass and the apparent mass is the mass of the alcohol displaced by the wood. The mass of the alcohol displaced is the volume of the wood times the density of the alcohol, the volume of the wood is the mass of the wood divided by the density of the wood, and the density of the alcohol is its specific gravity times the density of water.

$$m_{\text{actual}} - m_{\text{apparent}} = \rho_{\text{alc}} V_{\text{wood}} = \rho_{\text{alc}} \frac{m_{\text{actual}}}{\rho_{\text{wood}}} = SG_{\text{alc}} \rho_{\text{H}_2\text{O}} \frac{m_{\text{actual}}}{\rho_{\text{wood}}} \rightarrow$$

$$\frac{\rho_{\text{wood}}}{\rho_{\text{H}_2\text{O}}} = SG_{\text{wood}} = SG_{\text{alc}} \frac{m_{\text{actual}}}{(m_{\text{actual}} - m_{\text{apparent}})} = (0.79) \frac{0.48 \text{ kg}}{(0.48 \text{ kg} - 0.047 \text{ kg})} = \boxed{0.88}$$

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

$$F_{\text{buoyant}} = W_{\text{ice}} \rightarrow m_{\text{seawater submerged}} g = m_{\text{ice}} g \rightarrow m_{\text{seawater submerged}} = m_{\text{ice}} \rightarrow$$

$$\rho_{\text{seawater}} V_{\text{seawater}} = \rho_{\text{ice}} V_{\text{ice}} \rightarrow (SG)_{\text{seawater}} \rho_{\text{water}} V_{\text{submerged ice}} = (SG)_{\text{ice}} \rho_{\text{water}} V_{\text{ice}} \rightarrow$$

$$(SG)_{\text{seawater}} V_{\text{submerged ice}} = (SG)_{\text{ice}} V_{\text{ice}} \rightarrow$$

$$V_{\text{submerged ice}} = \frac{(SG)_{\text{ice}}}{(SG)_{\text{seawater}}} V_{\text{ice}} = \frac{0.917}{1.025} V_{\text{ice}} = 0.895 V_{\text{ice}}$$

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

34. For the combination to just barely sink, the total weight of the wood and lead must be equal to the total buoyant force on the wood and the lead.

$$F_{\text{weight}} = F_{\text{buoyant}} \rightarrow m_{\text{wood}} g + m_{\text{Pb}} g = V_{\text{wood}} \rho_{\text{water}} g + V_{\text{Pb}} \rho_{\text{water}} g \rightarrow$$

$$m_{\text{wood}} + m_{\text{Pb}} = \frac{m_{\text{wood}}}{\rho_{\text{wood}}} \rho_{\text{water}} + \frac{m_{\text{Pb}}}{\rho_{\text{Pb}}} \rho_{\text{water}} \rightarrow m_{\text{Pb}} \left( 1 - \frac{\rho_{\text{water}}}{\rho_{\text{Pb}}} \right) = m_{\text{wood}} \left( \frac{\rho_{\text{water}}}{\rho_{\text{wood}}} - 1 \right) \rightarrow$$

$$m_{\text{pb}} = m_{\text{wood}} \frac{\left( \frac{\rho_{\text{water}}}{\rho_{\text{wood}}} - 1 \right)}{\left( 1 - \frac{\rho_{\text{water}}}{\rho_{\text{Pb}}} \right)} = m_{\text{wood}} \frac{\left( \frac{1}{SG_{\text{wood}}} - 1 \right)}{\left( 1 - \frac{1}{SG_{\text{Pb}}} \right)} = (5.25 \text{ kg}) \frac{\left( \frac{1}{0.50} - 1 \right)}{\left( 1 - \frac{1}{11.3} \right)} = \boxed{5.76 \text{ kg}}$$

35. Use Eq. 10-4b, the equation of continuity for an incompressible fluid, to compare blood flow in the aorta and in the major arteries.

$$(Av)_{\text{aorta}} = (Av)_{\text{arteries}} \rightarrow$$

$$v_{\text{arteries}} = \frac{A_{\text{aorta}}}{A_{\text{arteries}}} v_{\text{aorta}} = \frac{\pi (1.2 \text{ cm})^2}{2.0 \text{ cm}^2} (40 \text{ cm/s}) = 90.5 \text{ cm/s} \approx \boxed{0.9 \text{ m/s}}$$

36. We apply the equation of continuity at constant density, Eq. 10-4b.

Flow rate out of duct = Flow rate into room

$$A_{\text{duct}} v_{\text{duct}} = \pi r^2 v_{\text{duct}} = \frac{V_{\text{room}}}{t_{\text{to fill room}}} \rightarrow v_{\text{duct}} = \frac{V_{\text{room}}}{\pi r^2 t_{\text{to fill room}}} = \frac{(9.2 \text{ m})(5.0 \text{ m})(4.5 \text{ m})}{\pi (0.15 \text{ m})^2 (16 \text{ min}) \left( \frac{60 \text{ s}}{1 \text{ min}} \right)} = \boxed{3.1 \text{ m/s}}$$

37. Bernoulli's equation is evaluated with  $v_1 = v_2 = 0$ . Let point 1 be the initial point, and point 2 be the final point.

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

$$P_2 - P_1 = \rho g (y_1 - y_2) \rightarrow \Delta P = -\rho g \Delta y$$

But a change in  $y$  coordinate is the opposite of the change in depth which is what is represented in Eq. 10-3b. So our final result is  $\Delta P = \rho g \Delta h$ , Eq. 10-3b.

38. We may apply Torricelli's theorem., Eq. 10-6.

$$v_1 = \sqrt{2g(y_2 - y_1)} = \sqrt{2(9.80 \text{ m/s}^2)(4.6 \text{ m})} = \boxed{9.5 \text{ m/s}}$$

39. The volume flow rate of water from the hose, multiplied times the time of filling, must equal the volume of the pool.

$$(Av)_{\text{hose}} = \frac{V_{\text{pool}}}{t} \rightarrow t = \frac{V_{\text{pool}}}{A_{\text{hose}} v_{\text{hose}}} = \frac{\pi (3.05 \text{ m})^2 (1.2 \text{ m})}{\pi \left[ \frac{1}{2} \left( \frac{5}{8} \right) \left( \frac{1 \text{ m}}{39.37} \right) \right]^2 (0.40 \text{ m/s})} = 4.429 \times 10^5 \text{ s}$$

$$4.429 \times 10^5 \text{ s} \left( \frac{1 \text{ day}}{60 \times 60 \times 24 \text{ s}} \right) = \boxed{5.1 \text{ days}}$$

40. 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.

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

$$P_1 - P_{\text{atm}} = \rho g y_2 = (1.00 \times 10^3 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(15 \text{ m}) = \boxed{1.5 \times 10^5 \text{ N/m}^2}$$

41. Use the equation of continuity (Eq. 10-4) to relate the volume flow of water at the two locations, and use Bernoulli's equation (Eq. 10-5) 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. We use subscript "1" for the larger diameter, and subscript "2" for the smaller diameter.

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

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

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

$$A_1 v_1 = \pi r_1^2 \sqrt{\frac{2(P_1 - P_2)}{\rho \left( \frac{r_1^4}{r_2^4} - 1 \right)}} = \pi (3.0 \times 10^{-2} \text{ m})^2 \sqrt{\frac{2(32.0 \times 10^3 \text{ Pa} - 24.0 \times 10^3 \text{ Pa})}{(1.0 \times 10^3 \text{ kg/m}^3) \left( \frac{(3.0 \times 10^{-2} \text{ m})^4}{(2.0 \times 10^{-2} \text{ m})^4} - 1 \right)}}$$

$$= \boxed{5.6 \times 10^{-3} \text{ m}^3/\text{s}}$$

42. The pressure head can be interpreted as an initial height for the water, with a speed of 0 and atmospheric pressure. Apply Bernoulli's equation to the faucet location and the pressure head location to find the speed of the water at the faucet, and then calculate the volume flow rate. Since the faucet is open, the pressure there will be atmospheric as well.

$$P_{\text{faucet}} + \frac{1}{2} \rho v_{\text{faucet}}^2 + \rho g y_{\text{faucet}} = P_{\text{head}} + \frac{1}{2} \rho v_{\text{head}}^2 + \rho g y_{\text{head}} \rightarrow$$

$$v_{\text{faucet}}^2 = \frac{2}{\rho} (P_{\text{head}} - P_{\text{faucet}}) + v_{\text{head}}^2 + 2g(y_{\text{head}} - y_{\text{faucet}}) = 2gy_{\text{head}} \rightarrow$$

$$v_{\text{faucet}} = \sqrt{2gy_{\text{head}}}$$

$$\text{Volume flow rate} = Av = \pi r^2 \sqrt{2gy_{\text{head}}} = \pi \left[ \frac{1}{2} (1.85 \times 10^{-2} \text{ m}) \right]^2 \sqrt{2(9.80 \text{ m/s}^2)(15.0 \text{ m})}$$

$$= \boxed{4.6 \times 10^{-3} \text{ m}^3/\text{s}}$$

43. 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.

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

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

$$F_{\text{air}} = \frac{1}{2} \rho_{\text{air}} v_{\text{outside}}^2 A_{\text{roof}} = \frac{1}{2} (1.29 \text{ kg/m}^3) (35 \text{ m/s})^2 (240 \text{ m}^2) = \boxed{1.9 \times 10^5 \text{ N}}$$

44. 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.

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

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

$$= \frac{1}{2} (1.29 \text{ kg/m}^3) [(260 \text{ m/s})^2 - (150 \text{ m/s})^2] (78 \text{ m}^2) = \boxed{2.3 \times 10^6 \text{ N}}$$

45. The air pressure inside the hurricane can be estimated using Bernoulli's equation. Assume the pressure outside the hurricane is air pressure, the speed of the wind outside the hurricane is 0, and that the two pressure measurements are made at the same height.

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

$$P_{\text{inside}} = P_{\text{outside}} - \frac{1}{2} \rho v_{\text{air}}^2$$

$$= 1.013 \times 10^5 \text{ Pa} - \frac{1}{2} (1.29 \text{ kg/m}^3) \left[ (300 \text{ km/h}) \left( \frac{1000 \text{ m}}{\text{km}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) \right]^2$$

$$= \boxed{9.7 \times 10^4 \text{ Pa}} \approx 0.96 \text{ atm}$$

46. Use the equation of continuity (Eq. 10-4) to relate the volume flow of water at the two locations, and use Bernoulli's equation (Eq. 10-5) to relate the conditions at the street to those at the top floor. Express the pressures as atmospheric pressure plus gauge pressure.

$$A_{\text{street}} v_{\text{street}} = A_{\text{top}} v_{\text{top}} \rightarrow$$

$$v_{\text{top}} = v_{\text{street}} \frac{A_{\text{street}}}{A_{\text{top}}} = (0.60 \text{ m/s}) \frac{\pi (5.0 \times 10^{-2} \text{ m})^2}{\pi (2.6 \times 10^{-2} \text{ m})^2} = 2.219 \text{ m/s} \approx \boxed{2.2 \text{ m/s}}$$

$$P_0 + P_{\text{gauge street}} + \frac{1}{2} \rho v_{\text{street}}^2 + \rho g y_{\text{street}} = P_0 + P_{\text{gauge top}} + \frac{1}{2} \rho v_{\text{top}}^2 + \rho g y_{\text{top}} \rightarrow$$

$$P_{\text{gauge top}} = P_{\text{gauge street}} + \frac{1}{2} \rho (v_{\text{street}}^2 - v_{\text{top}}^2) + \rho g y (y_{\text{street}} - y_{\text{top}})$$

$$= (3.8 \text{ atm}) \left( \frac{1.013 \times 10^5 \text{ Pa}}{\text{atm}} \right) + \frac{1}{2} (1.00 \times 10^3 \text{ kg/m}^3) [(0.60 \text{ m/s})^2 - (2.219 \text{ m/s})^2]^2$$

$$+ (1.00 \times 10^3 \text{ kg/m}^3) (9.8 \text{ m/s}^2) (-18 \text{ m})$$

$$= 2.063 \times 10^5 \text{ Pa} \left( \frac{1 \text{ atm}}{1.013 \times 10^5 \text{ Pa}} \right) \approx \boxed{2.0 \text{ atm}}$$

47. (a) Apply the equation of continuity and Bernoulli's equation at the same height to the wide and narrow portions of the tube.

$$A_2 v_2 = A_1 v_1 \rightarrow v_2 = v_1 \frac{A_1}{A_2}$$

$$P_1 + \frac{1}{2} \rho v_1^2 = P_2 + \frac{1}{2} \rho v_2^2 \rightarrow \frac{2(P_1 - P_2)}{\rho} = v_2^2 - v_1^2 \rightarrow$$

$$\left( v_1 \frac{A_1}{A_2} \right)^2 - v_1^2 = \frac{2(P_1 - P_2)}{\rho} \rightarrow v_1^2 \left( \frac{A_1^2}{A_2^2} - \frac{A_2^2}{A_2^2} \right) = \frac{2(P_1 - P_2)}{\rho} \rightarrow$$

$$v_1^2 = \frac{2A_2^2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)} \rightarrow v_1 = A_2 \sqrt{\frac{2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)}}$$

$$(b) \quad v_1 = A_2 \sqrt{\frac{2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)}}$$

$$= \pi \left[ \frac{1}{2} (0.010 \text{ m}) \right]^2 \sqrt{\frac{2(18 \text{ mm Hg}) \left( \frac{133 \text{ N/m}^2}{\text{mm Hg}} \right)}{(1000 \text{ kg/m}^3) \left( \pi^2 \left[ \frac{1}{2} (0.030 \text{ m}) \right]^4 - \pi^2 \left[ \frac{1}{2} (0.010 \text{ m}) \right]^4 \right)}} = \boxed{0.24 \text{ m/s}}$$

48. Apply both Bernoulli's equation and the equation of continuity between the two openings of the tank. Note that the pressure at each opening will be atmospheric pressure.

$$A_2 v_2 = A_1 v_1 \rightarrow v_2 = v_1 \frac{A_1}{A_2}$$

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

$$v_1^2 - \left( v_1 \frac{A_1}{A_2} \right)^2 = 2gh \rightarrow v_1^2 \left( 1 - \frac{A_1^2}{A_2^2} \right) = 2gh \rightarrow v_1 = \sqrt{\frac{2gh}{(1 - A_1^2/A_2^2)}}$$

49. Use Bernoulli's equation to find the speed of the liquid as it leaves the opening, assuming that the speed of the liquid at the top is 0, and that the pressure at each opening is air pressure.

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2 \rightarrow v_1 = \sqrt{2g(h_2 - h_1)}$$

- (a) Since the liquid is launched horizontally, the initial vertical speed is zero. Use Eq. 2-11(a) for constant acceleration to find the time of fall, with upward as the positive direction. Then multiply the time of fall times  $v_1$ , the (constant) horizontal speed.

$$y = y_0 + v_{0y}t + \frac{1}{2} a_y t^2 \rightarrow 0 = h_1 + 0 - \frac{1}{2} g t^2 \rightarrow t = \sqrt{\frac{2h_1}{g}}$$

$$\Delta x = v_1 t = \sqrt{2g(h_2 - h_1)} \sqrt{\frac{2h_1}{g}} = \boxed{2\sqrt{(h_2 - h_1)h_1}}$$

- (b) We seek some height  $h_1'$  such that  $2\sqrt{(h_2 - h_1)h_1} = 2\sqrt{(h_2 - h_1')h_1'}$ .

$$2\sqrt{(h_2 - h_1)h_1} = 2\sqrt{(h_2 - h_1')h_1'} \rightarrow (h_2 - h_1)h_1 = (h_2 - h_1')h_1' \rightarrow$$

$$h_1'^2 - h_2 h_1' + (h_2 - h_1)h_1 = 0 \rightarrow$$

$$h_1' = \frac{h_2 \pm \sqrt{h_2^2 - 4(h_2 - h_1)h_1}}{2} = \frac{h_2 \pm \sqrt{h_2^2 - 4h_1 h_2 + 4h_1^2}}{2} = \frac{h_2 \pm (h_2 - 2h_1)}{2} = \frac{2h_2 - 2h_1}{2}, \frac{2h_1}{2}$$

$$\boxed{h_1' = h_2 - h_1}$$

50. Apply Eq. 10-8. Use the average radius to calculate the plate area.

$$F = \eta A \frac{v}{l} \rightarrow \eta = \frac{Fl}{Av} = \frac{\left(\frac{\tau}{r_{\text{inner}}}\right)(r_{\text{outer}} - r_{\text{inner}})}{(2\pi r_{\text{avg}} h)(\omega r_{\text{inner}})}$$

$$= \frac{\left(\frac{0.024 \text{ m}\cdot\text{N}}{0.0510 \text{ m}}\right)(0.20 \times 10^{-2} \text{ m})}{2\pi(0.0520 \text{ m})(0.120 \text{ m})\left(62 \frac{\text{rev}}{\text{min}} \times \frac{2\pi \text{ rad}}{\text{rev}} \times \frac{1 \text{ min}}{60 \text{ s}}\right)(0.0510 \text{ m})} = \boxed{7.2 \times 10^{-2} \text{ Pa}\cdot\text{s}}$$

51. From Poiseuille's equation, the volume flow rate  $Q$  is proportional to  $R^4$  if all other factors are the same. Thus  $Q/R^4 = \frac{V}{t} \frac{1}{R^4}$  is constant. If the volume of water used to water the garden is to be same in both cases, then  $tR^4$  is constant.

$$t_1 R_1^4 = t_2 R_2^4 \rightarrow t_2 = t_1 \left(\frac{R_1}{R_2}\right)^4 = t_1 \left(\frac{3/8}{5/8}\right)^4 = 0.13 t_1$$

Thus the time has been cut by 87%.

52. Use Poiseuille's equation to find the pressure difference.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta L} \rightarrow$$

$$(P_2 - P_1) = \frac{8Q\eta L}{\pi R^4} = \frac{8 \left[ 5.6 \times 10^{-3} \frac{\text{L}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{1 \times 10^{-3} \text{ m}^3}{1 \text{ L}} \right] (0.2 \text{ Pa}\cdot\text{s}) (5.5 \times 10^{-2} \text{ m})}{\pi (0.9 \times 10^{-3} \text{ m})^4}$$

$$= \boxed{4.0 \times 10^3 \text{ Pa}}$$

53. Use Poiseuille's equation to find the pressure difference.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta L} \rightarrow$$

$$(P_2 - P_1) = \frac{8Q\eta L}{\pi R^4} = \frac{8(450 \text{ cm}^3/\text{s})(10^{-6} \text{ m}^3/\text{cm}^3)(0.20 \text{ Pa}\cdot\text{s})(1.9 \times 10^3 \text{ m})}{\pi (0.145 \text{ m})^4} = 985.1 \text{ Pa} \approx \boxed{990 \text{ Pa}}$$

54. Use Poiseuille's equation to find the radius, and then double the radius to the diameter.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta L} \rightarrow$$

$$d = 2R = 2 \left[ \frac{8\eta L Q}{\pi (P_2 - P_1)} \right]^{1/4} = 2 \left[ \frac{8(1.8 \times 10^{-5} \text{ Pa}\cdot\text{s})(21.0 \text{ m}) \left( \frac{9.0 \times 12.0 \times 4.0 \text{ m}^3}{600 \text{ s}} \right)}{\pi (0.71 \times 10^{-3} \text{ atm}) (1.013 \times 10^5 \text{ Pa/atm})} \right]^{1/4} = \boxed{0.11 \text{ m}}$$

55. The pressure drop per cm can be found from Poiseuille's equation, using a length of 1 cm. The volume flow rate is area of the aorta times the speed of the moving blood.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta L} \rightarrow$$

$$\frac{(P_2 - P_1)}{L} = \frac{8\eta Q}{\pi R^4} = \frac{8\eta \pi R^2 v}{\pi R^4} = \frac{8\eta v}{R^2} = \frac{8(4 \times 10^{-3} \text{ Pa}\cdot\text{s})(0.4 \text{ m/s})}{(1.2 \times 10^{-2} \text{ m})^2} = 88.9 \text{ Pa/m} = \boxed{0.89 \text{ Pa/cm}}$$

56. From Poiseuille's equation, the volume flow rate  $Q$  is proportional to  $R^4$  if all other factors are the same. Thus  $Q/R^4$  is constant.

$$\frac{Q_{\text{final}}}{R_{\text{final}}^4} = \frac{Q_{\text{initial}}}{R_{\text{initial}}^4} \rightarrow R_{\text{final}} = \left( \frac{Q_{\text{final}}}{Q_{\text{initial}}} \right)^{1/4} R_{\text{initial}} = (0.25)^{1/4} R_{\text{initial}} = 0.707 R_{\text{initial}}$$

Thus the radius has been reduced by about  $\boxed{29\%}$ .

57. (a)  $Re = \frac{2\bar{v}r\rho}{\eta} = \frac{2(0.40 \text{ cm/s})(1.2 \times 10^{-2} \text{ m})(1.05 \times 10^3 \text{ kg/m}^3)}{4 \times 10^{-3} \text{ Pa}\cdot\text{s}} = 2520$

The flow is  $\boxed{\text{turbulent}}$  at this speed.

- (b) Since the velocity is doubled the Reynolds number will double to 5040. The flow is  $\boxed{\text{turbulent}}$  at this speed.

58. The fluid pressure must be 18 torr higher than air pressure as it exits the needle, so that the blood will enter the vein. The pressure at the entrance to the needle must be higher than 18 torr, due to the viscosity of the blood. To produce that excess pressure, the blood reservoir is placed above the level of the needle. Use Poiseuille's equation to calculate the excess pressure needed due to the viscosity, and then use Eq. 10-3b to find the height of the blood reservoir necessary to produce that excess pressure.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta_{\text{blood}} L} \rightarrow P_2 = P_1 + \frac{8\eta_{\text{blood}} L Q}{\pi R^4} = \rho_{\text{blood}} g \Delta h \rightarrow$$

$$\Delta h = \frac{1}{\rho_{\text{blood}} g} \left( P_1 + \frac{8\eta_{\text{blood}} L Q}{\pi R^4} \right)$$

$$= \frac{1}{\left( 1.05 \times 10^3 \frac{\text{kg}}{\text{m}^3} \right) (9.80 \text{ m/s}^2)} \left( (18 \text{ mm-Hg}) \left( \frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}} \right) + \frac{8(4 \times 10^{-3} \text{ Pa}\cdot\text{s})(4.0 \times 10^{-2} \text{ m}) \left( \frac{4.0 \times 10^{-6} \text{ m}^3}{60 \text{ s}} \right)}{\pi (0.20 \times 10^{-3} \text{ m})^4} \right)$$

$$= \boxed{1.8 \text{ m}}$$

59. In Figure 10-35, we have  $\gamma = F/2L$ . Use this to calculate the force.

$$\gamma = \frac{F}{2L} = \frac{5.1 \times 10^{-3} \text{ N}}{2(0.070 \text{ m})} = \boxed{3.6 \times 10^{-2} \text{ N/m}}$$



60. As in Figure 10-35, there are 2 surfaces being increased, and so  $\gamma = F/2L$ . Use this relationship to calculate the force.

$$\gamma = F/2L \rightarrow F = 2\gamma L = 2(0.025 \text{ N/m})(0.182 \text{ m}) = \boxed{9.1 \times 10^{-3} \text{ N}}$$

61. From Example 10-14, we have that  $2\pi r\gamma \cos \theta = \frac{1}{6}mg$ . The maximum mass will occur at  $\theta = 0^\circ$ .

$$2\pi r\gamma \cos \theta = \frac{1}{6}mg \rightarrow m_{\max} = \frac{12\pi r\gamma}{g} = \frac{12\pi(3.0 \times 10^{-5} \text{ m})(0.072 \text{ N/m})}{9.80 \text{ m/s}^2} = 8.3 \times 10^{-6} \text{ kg}$$

This is much less than the insect's mass, and so the insect will not remain on top of the water.

62. (a) We assume that the weight of the platinum ring is negligible. Then the surface tension is the force to lift the ring, divided by the length of surface that is being pulled. Surface tension will

act at both edges of the ring, as in Figure 10-35 (b). Thus  $\gamma = \frac{F}{2(2\pi r)} = \frac{F}{4\pi r}$

(b)  $\gamma = \frac{F}{4\pi r} = \frac{8.40 \times 10^{-3} \text{ N}}{4\pi(2.8 \times 10^{-2} \text{ m})} = \boxed{2.4 \times 10^{-2} \text{ N/m}}$

63. The pressures for parts (a) and (b) stated in this problem are gauge pressures, relative to atmospheric pressure. The pressure change due to depth in a fluid is given by Eq. 10-3b,  $\Delta P = \rho g \Delta h$ .

(a) 
$$\Delta h = \frac{\Delta P}{\rho g} = \frac{(55 \text{ mm-Hg})\left(\frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}}\right)}{\left(1.00 \frac{\text{g}}{\text{cm}^3} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{10^6 \text{ cm}^3}{1 \text{ m}^3}\right)(9.80 \text{ m/s}^2)} = \boxed{0.75 \text{ m}}$$

(b) 
$$\Delta h = \frac{\Delta P}{\rho g} = \frac{(650 \text{ mm-H}_2\text{O})\left(\frac{9.81 \text{ N/m}^2}{1 \text{ mm-H}_2\text{O}}\right)}{\left(1.00 \frac{\text{g}}{\text{cm}^3} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{10^6 \text{ cm}^3}{1 \text{ m}^3}\right)(9.80 \text{ m/s}^2)} = \boxed{0.65 \text{ m}}$$

- (c) For the fluid to just barely enter the vein, the fluid pressure must be the same as the blood pressure.

$$\Delta h = \frac{\Delta P}{\rho g} = \frac{(18 \text{ mm-Hg})\left(\frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}}\right)}{\left(1.00 \frac{\text{g}}{\text{cm}^3} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{10^6 \text{ cm}^3}{1 \text{ m}^3}\right)(9.80 \text{ m/s}^2)} = \boxed{0.24 \text{ m}}$$

64. (a) The fluid in the needle is confined, and so Pascal's principle may be applied.

$$\begin{aligned} P_{\text{plunger}} = P_{\text{needle}} &\rightarrow \frac{F_{\text{plunger}}}{A_{\text{plunger}}} = \frac{F_{\text{needle}}}{A_{\text{needle}}} \rightarrow F_{\text{needle}} = F_{\text{plunger}} \frac{A_{\text{needle}}}{A_{\text{plunger}}} = F_{\text{plunger}} \frac{\pi r_{\text{needle}}^2}{\pi r_{\text{plunger}}^2} = F_{\text{plunger}} \frac{r_{\text{needle}}^2}{r_{\text{plunger}}^2} \\ &= (2.4 \text{ N}) \frac{(0.10 \times 10^{-3} \text{ m})^2}{(0.65 \times 10^{-2} \text{ m})^2} = \boxed{5.7 \times 10^{-4} \text{ N}} \end{aligned}$$

$$(b) F_{\text{plunger}} = P_{\text{plunger}} A_{\text{plunger}} (18 \text{ mm-Hg}) \left( \frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}} \right) \pi (0.65 \times 10^{-2} \text{ m})^2 = \boxed{0.32 \text{ N}}$$

65. The force can be found by multiplying the pressure times the area of the pump cylinder.

$$F_i = P_i A = (2.10 \times 10^5 \text{ N/m}^2) \pi (0.015 \text{ m})^2 = 1.5 \times 10^2 \text{ N}$$

$$F_f = P_f A = (3.10 \times 10^5 \text{ N/m}^2) \pi (0.015 \text{ m})^2 = 2.2 \times 10^2 \text{ N}$$

The range of forces is  $\boxed{1.5 \times 10^2 \text{ N} \leq F \leq 2.2 \times 10^2 \text{ N}}$

66. The pressure would be the weight of the ice divided by the area covered by the ice. The volume of the ice is represented by  $V$ , and its thickness by  $d$ . The volume is also the mass of the ice divided by the density of the ice.

$$P = \frac{F}{A} = \frac{mg}{V/d} = \frac{mgd}{V} = \frac{mgd}{m/\rho} = gd\rho = (9.80 \text{ m/s}^2)(3000 \text{ m})(917 \text{ kg/m}^3) = \boxed{2.7 \times 10^7 \text{ Pa}}$$

$$= 2.7 \times 10^7 \text{ Pa} \left( \frac{1 \text{ atm}}{1.013 \times 10^5 \text{ Pa}} \right) \approx \boxed{270 \text{ atm}}$$

67. The change in pressure with height is given by Eq. 10-3b.

$$\Delta P = \rho g \Delta h \rightarrow \frac{\Delta P}{P_0} = \frac{\rho g \Delta h}{P_0} = \frac{(1.29 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(380 \text{ m})}{1.013 \times 10^5 \text{ Pa}} = 0.047 \rightarrow$$

$$\boxed{\Delta P = 0.047 \text{ atm}}$$

68. (a) The input pressure is equal to the output pressure.

$$P_{\text{input}} = P_{\text{output}} \rightarrow \frac{F_{\text{input}}}{A_{\text{input}}} = \frac{F_{\text{output}}}{A_{\text{output}}} \rightarrow$$

$$A_{\text{input}} = A_{\text{output}} \frac{F_{\text{input}}}{F_{\text{output}}} = \pi (9.0 \times 10^{-2} \text{ m})^2 \frac{250 \text{ N}}{(970 \text{ kg})(9.80 \text{ m/s}^2)} = \boxed{6.7 \times 10^{-4} \text{ m}^2}$$

(b) The work is the force needed to lift the car (its weight) times the vertical distance lifted.

$$W = mgh = (970 \text{ kg})(9.80 \text{ m/s}^2)(0.12 \text{ m}) = 1.141 \times 10^3 \text{ J} \approx \boxed{1.1 \times 10^3 \text{ J}}$$

(c) The work done by the input piston is equal to the work done in lifting the car.

$$W_{\text{input}} = W_{\text{output}} \rightarrow F_{\text{input}} d_{\text{input}} = F_{\text{output}} d_{\text{output}} = mgh \rightarrow$$

$$h = \frac{F_{\text{input}} d_{\text{input}}}{mg} = \frac{(250 \text{ N})(0.13 \text{ m})}{(970 \text{ kg})(9.80 \text{ m/s}^2)} = 3.419 \times 10^{-3} \text{ m} \approx \boxed{3.4 \times 10^{-3} \text{ m}}$$

(d) The number of strokes is the full distance divided by the distance per stroke.

$$h_{\text{full}} = N h_{\text{stroke}} \rightarrow N = \frac{h_{\text{full}}}{h_{\text{stroke}}} = \frac{0.12 \text{ m}}{3.419 \times 10^{-3} \text{ m}} = \boxed{35 \text{ strokes}}$$

(e) The work input is the input force times the total distance moved by the input piston.

$$W_{\text{input}} = N F_{\text{input}} d_{\text{input}} \rightarrow 35(250 \text{ N})(0.13 \text{ m}) = \boxed{1.1 \times 10^3 \text{ J}}$$

Since the work input is equal to the work output, energy is conserved.

69. The change in pressure with height is given by Eq. 10-3b.

$$\Delta P = \rho g \Delta h \rightarrow \frac{\Delta P}{P_0} = \frac{\rho g \Delta h}{P_0} = \frac{(1.05 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(6 \text{ m})}{1.013 \times 10^5 \text{ Pa}} = 0.609 \rightarrow$$

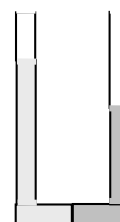
$$\boxed{\Delta P = 0.6 \text{ atm}}$$

70. The pressure change due to a change in height is given by Eq. 10-3b. That pressure is the excess force on the eardrum, divided by the area of the eardrum.

$$\Delta P = \rho g \Delta h = \frac{F}{A} \rightarrow$$

$$F = \rho g \Delta h A = (1.29 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(950 \text{ m})(0.50 \times 10^{-4} \text{ m}^2) = \boxed{0.60 \text{ N}}$$

71. The pressure at the top of each liquid will be atmospheric pressure, and the pressure at the place where the two fluids meet must be the same if the fluid is to be stationary. In the diagram, the darker color represents the water, and the lighter color represents the alcohol. Write the expression for the pressure at a depth for both liquids, starting at the top of each liquid with atmospheric pressure.



$$P_{\text{alcohol}} = P_0 + \rho_{\text{alcohol}} g \Delta h_{\text{alcohol}} = P_{\text{water}} = P_0 + \rho_{\text{water}} g \Delta h_{\text{water}} \rightarrow$$

$$\rho_{\text{alcohol}} \Delta h_{\text{alcohol}} = \rho_{\text{water}} \Delta h_{\text{water}} \rightarrow$$

$$\Delta h_{\text{water}} = \Delta h_{\text{alcohol}} \frac{\rho_{\text{alcohol}}}{\rho_{\text{water}}} = 18.0 \text{ cm} (0.79) = \boxed{14.2 \text{ cm}}$$

72. The buoyant force, equal to the weight of mantle displaced, must be equal to the weight of the continent. Let  $h$  represent the full height of the continent, and  $y$  represent the height of the continent above the surrounding rock.

$$W_{\text{continent}} = W_{\text{displaced mantle}} \rightarrow Ah\rho_{\text{continent}}g = A(h-y)\rho_{\text{mantle}}g \rightarrow$$

$$y = h \left( 1 - \frac{\rho_{\text{continent}}}{\rho_{\text{mantle}}} \right) = (35 \text{ km}) \left( 1 - \frac{2800 \text{ kg/m}^3}{3300 \text{ kg/m}^3} \right) = \boxed{5.3 \text{ km}}$$

73. The force is the pressure times the surface area.

$$F = PA = (120 \text{ mm-Hg}) \left( \frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}} \right) (82 \times 10^{-4} \text{ m}^2) = 130.9 \text{ N} \approx \boxed{130 \text{ N}}$$

74. We assume that the air pressure is due to the weight of the atmosphere, with the area equal to the surface area of the Earth.

$$P = \frac{F}{A} \rightarrow F = PA = mg \rightarrow$$

$$m = \frac{PA}{g} = \frac{4\pi R_{\text{Earth}}^2 P}{g} = \frac{4\pi (6.38 \times 10^6 \text{ m})^2 (1.013 \times 10^5 \text{ N/m}^2)}{9.80 \text{ m/s}^2} = \boxed{5.29 \times 10^{18} \text{ kg}}$$

75. The pressure difference due to the lungs is the pressure change in the column of water.

$$\Delta P = \rho g \Delta h \rightarrow \Delta h = \frac{\Delta P}{\rho g} = \frac{(80 \text{ mm-Hg}) \left( \frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}} \right)}{(1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = 1.086 \text{ m} \approx \boxed{1.1 \text{ m}}$$

76. The buoyant force due to the fresh water must be the weight of displaced seawater, and would be the volume of the displacement times the density of sea water times the acceleration due to gravity. But the buoyant force on the ship is also the weight of displaced sea water.

$$F_{\text{buoyant}} = V_{\text{displaced}} \rho_{\text{sea water}} g = m_{\text{fresh}} g \rightarrow m_{\text{fresh}} = (2650 \text{ m}^2)(8.50 \text{ m})(1025 \text{ kg/m}^3) = \boxed{2.31 \times 10^7 \text{ kg}}$$

This can also be expressed as a volume.

$$V_{\text{fresh}} = \frac{m_{\text{fresh}}}{\rho_{\text{fresh}}} = \frac{2.31 \times 10^7 \text{ kg}}{1.00 \times 10^3 \text{ kg/m}^3} = \boxed{2.31 \times 10^4 \text{ m}^3} = \boxed{2.31 \times 10^7 \text{ L}}$$

77. The buoyant force on the block of wood must be equal to the combined weight of the wood and copper.

$$(m_{\text{wood}} + m_{\text{Cu}})g = V_{\text{wood}} \rho_{\text{water}} g = \frac{m_{\text{wood}}}{\rho_{\text{wood}}} \rho_{\text{water}} g \rightarrow m_{\text{wood}} + m_{\text{Cu}} = \frac{m_{\text{wood}}}{\rho_{\text{wood}}} \rho_{\text{water}} \rightarrow$$

$$m_{\text{Cu}} = m_{\text{wood}} \left( \frac{\rho_{\text{water}}}{\rho_{\text{wood}}} - 1 \right) = (0.50 \text{ kg}) \left( \frac{1000 \text{ kg/m}^3}{600 \text{ kg/m}^3} - 1 \right) = \boxed{0.33 \text{ kg}}$$

78. The buoyant force must be equal to the weight of the water displaced by the full volume of the logs, and must also be equal to the full weight of the raft plus the passengers. Let  $N$  represent the number of passengers.

weight of water displaced by logs = weight of people + weight of logs

$$10V_{\text{log}} \rho_{\text{water}} g = Nm_{\text{person}} g + 10V_{\text{log}} \rho_{\text{log}} g \rightarrow$$

$$N = \frac{10V_{\text{log}} (\rho_{\text{water}} - \rho_{\text{log}})}{m_{\text{person}}} = \frac{10\pi r_{\text{log}}^2 l_{\text{log}} (\rho_{\text{water}} - SG_{\text{log}} \rho_{\text{water}})}{m_{\text{person}}} = \frac{10\pi r_{\text{log}}^2 l_{\text{log}} \rho_{\text{water}} (1 - SG_{\text{log}})}{m_{\text{person}}}$$

$$= \frac{10\pi (0.28 \text{ m})^2 (6.1 \text{ m})(1000 \text{ kg/m}^3)(1 - 0.60)}{68 \text{ kg}} = 88.37$$

Thus  $\boxed{88}$  people can stand on the raft without getting wet. When the 89<sup>th</sup> person gets on, the raft will sink.

79. The work done during each heartbeat is the force on the fluid times the distance that the fluid moves in the direction of the force.

$$W = F \Delta l = P A \Delta l = PV \rightarrow$$

$$\text{Power} = \frac{W}{t} = \frac{PV}{t} = \frac{(105 \text{ mm-Hg}) \left( \frac{133 \text{ N/m}^2}{1 \text{ mm-Hg}} \right) (70 \times 10^{-6} \text{ m}^3)}{\left( \frac{1}{70} \text{ min} \right) \left( \frac{60 \text{ s}}{\text{min}} \right)} = \boxed{1.1 \text{ W}}$$

80. The buoyant force on the rock is the force that would be on a mass of water with the same volume as the rock. Since the equivalent mass of water is accelerating upward, that same acceleration must be taken into account in the calculation of the buoyant force.

$$\begin{aligned}
 F_{\text{buoyant}} - m_{\text{water}}g &= m_{\text{water}}a \rightarrow \\
 F_{\text{buoyant}} &= m_{\text{water}}(g+a) = V_{\text{water}}\rho_{\text{water}}(g+a) = V_{\text{rock}}\rho_{\text{water}}(g+a) \\
 &= \frac{m_{\text{rock}}}{\rho_{\text{rock}}}\rho_{\text{water}}(g+a) = \frac{m_{\text{rock}}}{SG_{\text{rock}}}(g+a) = \frac{(3.0\text{ kg})3.4(9.80\text{ m/s}^2)}{2.7} = \boxed{37\text{ N}}
 \end{aligned}$$

For the rock to not sink, the upward buoyant force on the rock minus the weight of the rock must be equal to the net force on the rock.

$$F_{\text{buoyant}} - m_{\text{rock}}g = m_{\text{rock}}a \rightarrow F_{\text{buoyant}} = m_{\text{rock}}(g+a) = (3.0\text{ kg})3.4(9.80\text{ m/s}^2) = 100\text{ N}$$

The rock will sink, because the buoyant force is not large enough to “float” the rock.

81. The pressure head can be interpreted as an initial height for the water, with a speed of 0 and atmospheric pressure. Apply Bernoulli’s equation to the faucet location and the pressure head location to find the speed of the water at the faucet. Since the faucet is open, the pressure there will be atmospheric as well.

$$\begin{aligned}
 P_{\text{faucet}} + \frac{1}{2}\rho v_{\text{faucet}}^2 + \rho g y_{\text{faucet}} &= P_{\text{head}} + \frac{1}{2}\rho v_{\text{head}}^2 + \rho g y_{\text{head}} \rightarrow \\
 y_{\text{head}} &= \frac{v_{\text{faucet}}^2}{2g} = \frac{(9.5\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = \boxed{4.6\text{ m}}
 \end{aligned}$$

82. 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  $y_0 = y$ .

$$\begin{aligned}
 A_0 v_0 &= A_1 v_1 \rightarrow v_1 = v_0 \frac{A_0}{A_1} = v_0 \frac{\pi(d_0/2)^2}{\pi(d_1/2)^2} = v_0 \frac{d_0^2}{d_1^2} \rightarrow \\
 P_0 + \frac{1}{2}\rho v_0^2 + \rho g y_0 &= P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 \rightarrow v_0^2 + 2gy = v_1^2 = v_0^2 \frac{d_0^4}{d_1^4} \rightarrow \\
 \boxed{d_1} &= d_0 \left( \frac{v_0^2}{v_0^2 + 2gy} \right)^{1/4}
 \end{aligned}$$

83. (a) We assume that the water is launched at ground level. Since it also lands at ground level, the level range formula from chapter 4 may be used.

$$R = \frac{v_0^2 \sin 2\theta}{g} \rightarrow v_0 = \sqrt{\frac{Rg}{\sin 2\theta}} = \sqrt{\frac{(8.0\text{ m})(9.80\text{ m/s}^2)}{\sin 70^\circ}} = 9.134\text{ m/s} \approx \boxed{9.1\text{ m/s}}$$

- (b) The volume rate of flow is the area of the flow times the speed of the flow. Multiply by 4 for the 4 heads.

$$\begin{aligned}
 \text{Volume flow rate} &= Av = 4\pi r^2 v = 4\pi (1.5 \times 10^{-3}\text{ m})^2 (9.134\text{ m/s}) \\
 &= 2.583 \times 10^{-4}\text{ m}^3/\text{s} \left( \frac{1\text{ L}}{1.0 \times 10^{-3}\text{ m}^3} \right) \approx \boxed{0.26\text{ L/s}}
 \end{aligned}$$

- (c) Use the equation of continuity to calculate the flow rate in the supply pipe.

$$(Av)_{\text{supply}} = (Av)_{\text{heads}} \rightarrow v_{\text{supply}} = \frac{(Av)_{\text{heads}}}{A_{\text{supply}}} = \frac{2.583 \times 10^{-4} \text{ m}^3/\text{s}}{\pi (0.95 \times 10^{-2} \text{ m})^2} = \boxed{0.91 \text{ m/s}}$$

84. (a) We assume that the tube in the pail is about 4.0 cm below the surface of the liquid in the pail so that the pressure at that two tube ends is approximately the same. Apply Bernoulli's equation between the two ends of the tube.

$$P_{\text{sink}} + \frac{1}{2} \rho v_{\text{sink}}^2 + \rho g y_{\text{sink}} = P_{\text{pail}} + \frac{1}{2} \rho v_{\text{pail}}^2 + \rho g y_{\text{pail}} \rightarrow$$

$$v_{\text{pail}} = \sqrt{2g(y_{\text{sink}} - y_{\text{pail}})} = \sqrt{2(9.80 \text{ m/s}^2)(0.50 \text{ m})} = 3.130 \text{ m/s} \approx \boxed{3.1 \text{ m/s}}$$

- (b) The volume flow rate (at the pail end of the tube) times the time must equal the volume of water in the sink.

$$(Av)_{\text{pail}} t = V_{\text{sink}} \rightarrow t = \frac{V_{\text{sink}}}{(Av)_{\text{pail}}} = \frac{(0.48 \text{ m}^2)(4.0 \times 10^{-2} \text{ m})}{\pi (1.0 \times 10^{-2} \text{ m})^2 (3.13 \text{ m/s})} = \boxed{20 \text{ s}}$$

85. We assume that the speed of the water at the entry point to the siphon tube is zero, and we assume that the pressure at both ends of the siphon hose is the same.

$$P_{\text{top}} + \frac{1}{2} \rho v_{\text{top}}^2 + \rho g y_{\text{top}} = P_{\text{bottom}} + \frac{1}{2} \rho v_{\text{bottom}}^2 + \rho g y_{\text{bottom}} \rightarrow v_{\text{bottom}} = \sqrt{2g(y_{\text{top}} - y_{\text{bottom}})}$$

$$Av = \pi r_{\text{tube}}^2 v_{\text{bottom}} = \pi r_{\text{tube}}^2 \sqrt{2g(y_{\text{top}} - y_{\text{bottom}})} = \pi (0.60 \times 10^{-2} \text{ m})^2 \sqrt{2(9.80 \text{ m/s}^2)(0.64 \text{ m})}$$

$$= \boxed{4.0 \times 10^{-4} \text{ m}^3/\text{s}}$$

86. The upward force due to air pressure on the bottom of the wing must be equal to the weight of the airplane plus the downward force due to air pressure on the top of the wing. Bernoulli's equation can be used to relate the forces due to air pressure. We assume that there is no appreciable height difference between the top and the bottom of the wing.

$$P_{\text{top}} A + mg = P_{\text{bottom}} A \rightarrow (P_{\text{bottom}} - P_{\text{top}}) = \frac{mg}{A}$$

$$P_0 + P_{\text{bottom}} + \frac{1}{2} \rho v_{\text{bottom}}^2 + \rho g y_{\text{bottom}} = P_0 + P_{\text{top}} + \frac{1}{2} \rho v_{\text{top}}^2 + \rho g y_{\text{top}}$$

$$v_{\text{top}}^2 = \frac{2(P_{\text{bottom}} - P_{\text{top}})}{\rho} + v_{\text{bottom}}^2 \rightarrow$$

$$v_{\text{top}} = \sqrt{\frac{2(P_{\text{bottom}} - P_{\text{top}})}{\rho} + v_{\text{bottom}}^2} = \sqrt{\frac{2mg}{\rho A} + v_{\text{bottom}}^2} = \sqrt{\frac{2(2.0 \times 10^6 \text{ kg})(9.80 \text{ m/s}^2)}{(1.29 \text{ kg/m}^3)(1200 \text{ m}^2)} + (95 \text{ m/s})^2}$$

$$= 185.3 \text{ m/s} \approx \boxed{190 \text{ m/s}}$$

87. From Poiseuille's equation, the viscosity can be found from the volume flow rate, the geometry of the tube, and the pressure difference. The pressure difference over the length of the tube is the same as the pressure difference due to the height of the reservoir, assuming that the open end of the needle is at atmospheric pressure.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta L} ; P_2 - P_1 = \rho_{\text{blood}} g h \rightarrow$$

$$\eta = \frac{\pi R^4 (P_2 - P_1)}{8QL} = \frac{\pi R^4 \rho_{\text{blood}} gh}{8QL} = \frac{\pi (0.20 \times 10^{-3} \text{ m})^4 (1.05 \times 10^3 \text{ kg/m}^3) (9.80 \text{ m/s}^2) (1.70 \text{ m})}{8 \left[ 4.1 \frac{\text{cm}^3}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{10^{-6} \text{ m}^3}{\text{cm}^3} \right] (3.8 \times 10^{-2} \text{ m})}$$

$$= \boxed{4.2 \times 10^{-3} \text{ Pa}\cdot\text{s}}$$

88. From Poiseuille's equation, the volume flow rate  $Q$  is proportional to  $R^4$  if all other factors are the same. Thus  $Q/R^4$  is constant. Also, if the diameter is reduced by 15%, so is the radius.

$$\frac{Q_{\text{final}}}{R_{\text{final}}^4} = \frac{Q_{\text{initial}}}{R_{\text{initial}}^4} \rightarrow \frac{Q_{\text{final}}}{Q_{\text{initial}}} = \frac{R_{\text{final}}^4}{R_{\text{initial}}^4} = (0.85)^4 = 0.52$$

The flow rate is 52% of the original value.