10

FLUIDS

Responses 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 sharp end of the pin (with a smaller area) will pierce the skin when pushed with a certain minimum force, but 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 the skin is pierced.

3. As the water boils, steam displaces some of the air in the can. With the lid off, the pressure inside is the same as the outside pressure. When the lid is put on, and the water and the can cool, the steam that is trapped in the can condenses back into liquid water. This reduces the pressure in the can to less than atmospheric pressure, and the greater force from the outside air pressure crushes the can.

4. Since the ice floats, the density of ice must be less than that of the water. The mass of the ice displaces a volume of water with the same weight as the ice, 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.

5. The density of ice $(917\ \text{kg/m}^3)$ is greater than that of alcohol $(790\ \text{kg/m}^3)$, so the ice cube will not float in a glass of alcohol. The ice cube will sink in the alcohol.

6. Both products have gas dissolved in them (carbonation), making their density less than that of water. The difference is in the sweetener in each product. The Coke® has a significant amount of sugar (or some other sweetener, like high-fructose corn syrup) dissolved in it, increasing its density so that it is greater than that of water. The Diet Coke® has a different, low-calorie sweetener that evidently has a lower density than the Coke sweetener. The density of the Diet Coke (including the can) remains less than that of water. Thus, the Coke sinks, and the Diet Coke floats.

7. 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 ship is less than the density of water, so ships made of iron float.

8. Sand must be added to the barge. If sand is removed, then the barge will not need to displace as much water since its weight will be less, and it will rise up in the water, making it even less likely to fit under the bridge. If sand is added, then the barge will sink lower into the water, making it more likely to fit under the bridge. You would have to be careful to not pile the sand up so high that you lose the advantage of adding more sand.

9. As the balloon rises, the air pressure outside the balloon will decrease, becoming 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, then 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 its maximum volume.

10. No. If the balloon is inflated, then the pressure inside the balloon is slightly greater than atmospheric pressure. Thus the air inside the balloon is more dense than the air outside the balloon. Because of the higher density, the weight of the air inside the balloon is greater than the weight of the outside air that has been displaced. This is the same as saying that the buoyant force on the balloon is less than the weight of the air inside the balloon. Therefore, the apparent weight of the filled balloon will be slightly greater than that of the empty balloon.

11. In order to float, you must displace an amount of water equal to your own weight. Salt water is more dense than fresh water, so the volume of salt water you must displace is less than the volume of fresh water. You will float higher in the salt water because you are displacing less water. Less of your body needs to be submerged in the water.

12. As the water falls, its vertical speed is larger when away from the faucet than when close to it, due to 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.

13. 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 farther from the train. That difference in pressure results in a force toward the train, which could push a lightweight child toward the train. The child would be pushed, not "sucked," but the effect would be the same—a net force toward the train.

14. 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), so the cup and water would fall together. For the water to flow out of the holes while falling, the water would have to 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.

15. The lift generated by wind depends on the speed of the air relative to the wing. For example, an airplane model in a wind tunnel will have lift forces on it 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.

16. As the ships move, they drag water with them. The moving water has a lower pressure than stationary water, as shown by Bernoulli's principle. If the ships are moving in parallel paths fairly close together, then the water between them will have a lower pressure than the water on the outside of either one, since it is being dragged by both ships. The ships are in danger of colliding because the higher pressure of the water on the outsides will tend to push them toward each other.

17. The papers move toward each other. Bernoulli's principle says that as the speed of a gas increases, the pressure decreases (when there is no appreciable change in height). 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, 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 pushed off from the inside. By Bernoulli's principle, the fast moving winds of the storm causes 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 that 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. See the diagram in the textbook. The pressure at the surface of both containers is atmospheric pressure. The pressure in each tube would thus also 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 ρgh. 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 can occur.

21. "Blood pressure" should measure the pressure of the blood coming out of the heart. If the cuff is below the level of the heart, then the measured pressure will be the pressure from the pumping of the heart plus the pressure due to the height of blood above the cuff. This reading will be too high. Likewise, if the cuff is above heart level, then the reported pressure measurement will be too low.

Responses to MisConceptual Questions

1. (*c*) Students frequently think that since the wood floats, it experiences a greater buoyancy force. However, both objects experience the same buoyant force since they have the same volume and are in the same fluid. The wood floats because its weight is less than the buoyant force, and the iron sinks because its weight is greater than the buoyant force.

2. (*d*) A common misconception is that container B will have the greater force on the bottom since it holds the greatest weight of water. The force of the water on the bottom of the container is equal to the product of the area of the bottom and the pressure at the bottom. Since all three containers have the same base areas and the same depth of water, the forces on the bottom of each will be equal. The additional weight of the water in B is supported by the diagonal walls. The smaller weight of C is countered by the additional pressure exerted by the diagonal walls on the water.

3. (*c*) Students may think that since part of the wood floats above the water, beaker B will weigh more. Since the wood is in equilibrium, the weight of the water displaced by the wood is equal to the weight of the wood. Therefore, the beakers will weigh the same.

4. (*d*) A common misconception is to consider the ocean liner as a solid object. The ocean liner has an outer shell of steel, which keeps the water out of the interior of the ship. However, most of the volume occupied by the ocean liner is filled with air. This makes the average density of the ocean liner less than the density of the seawater. If a hole were introduced into the outer shell, then the interior would fill with water, increasing the density of the ship until it was greater than that of seawater and then the ship would sink, as happened to the Titanic.

5. i (*b*) and ii (*b*) When the rowboat is floating in the water, the boat will displace a volume of water whose weight is equal to the weight of the boat. When the boat (or the anchor) is removed from the swimming pool, the water is no longer being displaced, so the water level will drop back to its initial level.

6. (*c*) Students may think that since part of the ice floats above the water, the water will overflow as the ice melts. The ice, however, displaces a mass of water equal to the mass of the ice. As the ice melts, its volume decreases until it occupies the same volume as the water that the ice initially displaced.

7. (*a*) A common misconception is that the hot air causes the balloon to rise, so it would rise on the Moon just as it would on Earth. What actually happens on the Earth is the denser cold air around the balloon on Earth is heavier than the hot air in the balloon. This denser air then moves downward, displacing the hot air balloon upward. On the Moon there is no atmosphere to move downward around the balloon, so the balloon would not rise.

8. (*c*) Students may reason that since water is denser than oil, the object would experience a greater buoyant force in water. This would be true if the object was completely submerged in either fluid. Since the object is floating at the surface of the liquid, the buoyant force on the object will be equal to its weight and will therefore be the same in both fluids. The object floats with less volume submerged in the water than is submerged when it floats in the oil.

9. (*d*) The velocity of the water in the pipe depends upon its diameter, as shown by the continuity equation. The pressure depends upon both the change in elevation and the velocity of the water. Therefore, information about how the diameter changes is required to determine how the pressure changes.

10. (*a*) A common misconception is that the pressure would be higher in the faster moving water. The continuity equation requires that the water in the wider pipe travel slower than in the narrow pipe. Bernoulli’s equation shows that the pressure will be higher in the region where the water travels slower (the wider pipe). As water travels from a region of low pressure to one of high pressure, it experiences a retarding force, which decreases the velocity of the water.

11. (*b*) The ball accelerates to the right because the pressure on the left side of the ball is greater than the pressure on the right side. From Bernoulli’s equation, the air on the right side must then be traveling faster than the air on the left side. This difference in air speed is produced by spinning the ball when it is thrown.

12. (*a*) Students may believe that wind above the chimney will blow the smoke back down the chimney. Actually, the wind blowing across the top of the chimney causes the air pressure above the chimney to be lower than the air pressure inside. The greater inside pressure pushes the smoke up the chimney.

Solutions to Problems

1. The mass is found from the density of granite (found in Table 10–1) and the volume of granite.

$$m = \rho V = (2.7\times10^3\ \text{kg/m}^3)(10^8\ \text{m}^3) = 2.7\times10^{11}\ \text{kg} \approx \boxed{3\times10^{11}\ \text{kg}}$$

2. The mass is found from the density of air (found in Table 10–1) and the volume of air.

$$m = \rho V = (1.29\ \text{kg/m}^3)(5.6\ \text{m})(3.6\ \text{m})(2.4\ \text{m}) = \boxed{62\ \text{kg}}$$

3. The mass is found from the density of gold (found in Table 10–1) and the volume of gold.

$$m = \rho V = (19.3\times10^3\ \text{kg/m}^3)(0.54\ \text{m})(0.31\ \text{m})(0.22\ \text{m}) = \boxed{710\ \text{kg}} \quad (\approx 1\,600\ \text{lb})$$

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

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

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.

$$\text{SG}_{\text{fluid}} = \frac{\rho_{\text{fluid}}}{\rho_{\text{water}}} = \frac{(m/V)_{\text{fluid}}}{(m/V)_{\text{water}}} = \frac{m_{\text{fluid}}}{m_{\text{water}}} = \frac{89.22\ \text{g} - 35.00\ \text{g}}{98.44\ \text{g} - 35.00\ \text{g}} = \boxed{0.8547}$$

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.

$$m_{\text{antifreeze}} = \rho_{\text{antifreeze}} V_{\text{antifreeze}} = \text{SG}_{\text{antifreeze}} \rho_{\text{water}} V_{\text{antifreeze}} \qquad m_{\text{water}} = \rho_{\text{water}} V_{\text{water}}$$

$$\text{SG}_{\text{mixture}} = \frac{\rho_{\text{mixture}}}{\rho_{\text{water}}} = \frac{m_{\text{mixture}}/V_{\text{mixture}}}{\rho_{\text{water}}} = \frac{m_{\text{antifreeze}} + m_{\text{water}}}{\rho_{\text{water}} V_{\text{mixture}}} = \frac{\text{SG}_{\text{anti freeze}} \rho_{\text{water}} V_{\text{antifreeze}} + \rho_{\text{water}} V_{\text{water}}}{\rho_{\text{water}} V_{\text{mixture}}}$$

$$= \frac{\text{SG}_{\text{antifreeze}} V_{\text{antifreeze}} + V_{\text{water}}}{V_{\text{mixture}}} = \frac{(0.80)(4.0\ \text{L}) + 5.0\ \text{L}}{9.0\ \text{L}} = \boxed{0.91}$$

7. (*a*) The density from the three-part model is found from the total mass divided by the total volume. Let subscript 1 represent the inner core, subscript 2 represent the outer core, and subscript 3 represent the mantle. The radii are then the outer boundaries of the labeled region.

$$\rho_{\substack{\text{three}\\\text{layers}}} = \frac{m_1 + m_2 + m_3}{V_1 + V_2 + V_3} = \frac{\rho_1 m_1 + \rho_2 m_2 + \rho_3 m_3}{V_1 + V_2 + V_3} = \frac{\rho_1 \frac{4}{3}\pi r_1^3 + \rho_2 \frac{4}{3}\pi (r_2^3 - r_1^3) + \rho_3 \frac{4}{3}\pi (r_3^3 - r_2^3)}{\frac{4}{3}\pi r_1^3 + \frac{4}{3}\pi (r_2^3 - r_1^3) + \frac{4}{3}\pi (r_3^3 - r_2^3)}$$

$$= \frac{\rho_1 r_1^3 + \rho_2 (r_2^3 - r_1^3) + \rho_3 (r_3^3 - r_2^3)}{r_3^3} = \frac{r_1^3(\rho_1 - \rho_2) + r_2^3(\rho_2 - \rho_3) + r_3^3 \rho_3}{r_3^3}$$

$$= \frac{(1220\ \text{km})^3(1900\ \text{kg/m}^3) + (3480\ \text{km})^3(6700\ \text{kg/m}^3) + (6380\ \text{km})^3(4400\ \text{kg/m}^3)}{(6380\ \text{km})^3}$$

$$= 5500.6\ \text{kg/m}^3 \approx \boxed{5500\ \text{kg/m}^3}$$

(*b*) $$\rho_{\substack{\text{one}\\ \text{density}}} = \frac{M}{V} = \frac{M}{\frac{4}{3}\pi R^3} = \frac{5.98\times 10^{24}\ \text{kg}}{\frac{4}{3}\pi(6380\times 10^3\ \text{m})^3} = 5497.3\ \text{kg/m}^3 \approx \boxed{5.50\times 10^3\ \text{kg/m}^3}$$

$$\%\,\text{difference} = 100\left(\frac{\rho_{\substack{\text{one}\\ \text{density}}} - \rho_{\substack{\text{three}\\ \text{layers}}}}{\rho_{\substack{\text{three}\\ \text{layers}}}}\right) = 100\left(\frac{5497\ \text{kg/m}^3 - 5501\ \text{kg/m}^3}{5501\ \text{kg/m}^3}\right) = -0.073 \approx \boxed{-0.07\%}$$

8. The pressure is given by Eq. 10–3a.

$$P = \rho g h = (1.00\times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(46\ \text{m}) = \boxed{4.5\times 10^5\ \text{N/m}^2}$$

9. The pressure exerted by the heel is caused by the heel pushing down on the floor. That downward push is the reaction to the normal force of the floor on the shoe heel. The normal force on one heel is assumed to be half the weight of the person.

(*a*) $$P_{\text{pointed}} = \frac{\frac{1}{2}W_{\text{person}}}{A_{\text{pointed}}} = \frac{\frac{1}{2}(56\ \text{kg})(9.80\ \text{m/s}^2)}{(0.45\ \text{cm}^2)(0.01\ \text{m/cm})^2} = \boxed{6.1\times 10^6\ \text{N/m}^2}$$

(*b*) $$P_{\text{wide}} = \frac{\frac{1}{2}W_{\text{person}}}{A_{\text{wide}}} = \frac{\frac{1}{2}(56\ \text{kg})(9.80\ \text{m/s}^2)}{(16\ \text{cm}^2)(0.01\ \text{m/cm})^2} = \boxed{1.7\times 10^5\ \text{N/m}^2}$$

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

$$\Delta P = \rho g \Delta h = (1.05\times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(1.75\ \text{m})$$
$$= 1.801\times 10^4\ \text{N/m}^2\left(\frac{1\ \text{mm-Hg}}{133\ \text{N/m}^2}\right) = \boxed{135\ \text{mm-Hg}}$$

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

$$F = PA = (1.013\times 10^5\ \text{N/m}^2)(1.7\ \text{m})(2.6\ \text{m}) = \boxed{4.5\times 10^5\ \text{N}}$$

(*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, $\boxed{4.5\times 10^5\ \text{N}}$.

12. The height is found from Eq. 10–3a, using normal atmospheric pressure. The density is found in Table 10–1.

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

That is so tall as to be impractical in many cases.

13. The pressure difference on the lungs is the pressure change from the depth of water. The pressure unit conversion comes from Table 10–2.

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

He could have been 1.2 m below the surface.

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

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

$$m = \frac{P\pi r^2}{g} = \frac{(17.0\text{ atm})\left(\dfrac{1.013\times10^5\text{ N/m}^2}{1\text{ atm}}\right)\pi[\tfrac{1}{2}(0.255\text{ m})]^2}{(9.80\text{ m/s}^2)} = \boxed{8970\text{ kg}}$$

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

$$mg = 4PA \quad \rightarrow \quad m = \frac{4PA}{g} = \frac{4(2.40\times10^5\text{ N/m}^2)(190\text{ cm}^2)\left(\dfrac{1\text{ m}^2}{10^4\text{ cm}^2}\right)}{(9.80\text{ m/s}^2)} = 1861\text{ kg} \approx \boxed{1900\text{ kg}}$$

16. (*a*) The absolute pressure can be found from Eq. 10–3c, and the total force is the absolute pressure times the area of the bottom of the pool.

$$P = P_0 + \rho gh = 1.013\times10^5\text{ N/m}^2 + (1.00\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(1.8\text{ m})$$

$$= 1.189\times10^5\text{ N/m}^2 \approx \boxed{1.19\times10^5\text{ N/m}^2}$$

$$F = PA = (1.189\times10^5\text{ N/m}^2)(28.0\text{ m})(8.5\text{ m}) = \boxed{2.8\times10^7\text{ N}}$$

(*b*) The pressure against the side of the pool, near the bottom, will be the same as the pressure at the bottom. Pressure is not directional. $P = \boxed{1.19\times10^5\text{ N/m}^2}$.

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.

$$P_G = \rho gh = (1.00\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)[6.0\text{ m} + (75\text{ m})\sin 61^\circ] = \boxed{7.0\times10^5\text{ N/m}^2}$$

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

$$h = 6.0\text{ m} + (75\text{ m})\sin 61^\circ = \boxed{72\text{ m}}$$

18. The pressures at points a and b are equal since they are at the same height in the same fluid. If the pressures were unequal, then 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.

$$P_a = P_b \quad \rightarrow \quad P_0 + \rho_{oil} g h_{oil} = P_0 + \rho_{water} g h_{water} \quad \rightarrow \quad \rho_{oil} h_{oil} = \rho_{water} h_{water} \quad \rightarrow$$

$$\rho_{oil} = \frac{\rho_{water} h_{water}}{h_{oil}} = \frac{(1.00\times10^3\text{ kg/m}^3)(0.272\text{ m} - 0.0862\text{ m})}{(0.272\text{ m})} = \boxed{683\text{ kg/m}^3}$$

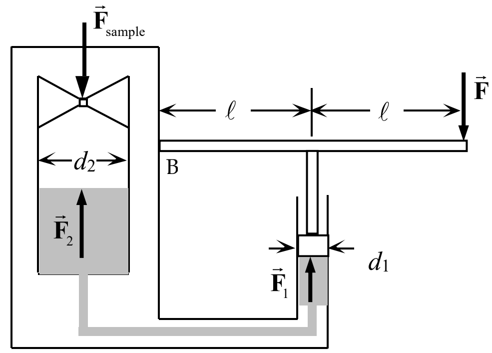
19. If the atmosphere were of uniform density, then the pressure at any height *h* would be $P = P_0 - \rho gh$. At the top of the uniform atmosphere, the pressure would be 0. Thus solve for the height at which the pressure becomes 0, using a density of half of the atmospheric density at sea level.

$$P = P_0 - \rho gh = 0 \quad \rightarrow \quad h = \frac{P_0}{\rho g} = \frac{(1.013\times10^5\text{ N/m}^2)}{\tfrac{1}{2}(1.29\text{ kg/m}^3)(9.80\text{ m/s}^2)} = \boxed{1.60\times10^4\text{ m}}$$

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

$$P_G = \rho gh = (1.00\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(44\ \text{m}) = \boxed{4.3\times10^5\ \text{N/m}^2}$$

21. Consider the lever (handle) of the press. The net torque on that handle is 0. Use that to find the force exerted by the hydraulic fluid upward on the small cylinder (and the lever). Then Pascal's principle can be used to find the upward force on the large cylinder, which is the same as the force on the sample.



$$\sum\tau = F(2\ell) - F_1\ell = 0 \rightarrow F_1 = 2F$$

$$P_1 = P_2 \quad \rightarrow \quad \frac{F_1}{\pi\left(\frac{1}{2}d_1\right)^2} = \frac{F_2}{\pi\left(\frac{1}{2}d_2\right)^2} \quad \rightarrow$$

$$F_2 = F_1(d_2/d_1)^2 = 2F(d_2/d_1)^2 = F_{\text{sample}} \quad \rightarrow$$

$$P_{\text{sample}} = \frac{F_{\text{sample}}}{A_{\text{sample}}} = \frac{2F(d_2/d_1)^2}{A_{\text{sample}}} = \frac{2(320\ \text{N})(5)^2}{4.0\times10^{-4}\ \text{m}^2} = \boxed{4.0\times10^7\ \text{N/m}^2}$$

22. 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*) $P = P_0 + \rho gh = 1.04\ \text{bar} + \rho_{\text{Hg}}gh$

$$= (1.04\ \text{bar})\left(\frac{1.00\times10^5\ \text{N/m}^2}{1\ \text{bar}}\right) + (13.6\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(0.185\ \text{m}) = \boxed{1.29\times10^5\ \text{N/m}^2}$$

(*b*) $$P = (1.04\ \text{bar})\left(\frac{1.00\times10^5\ \text{N/m}^2}{1\ \text{bar}}\right) + (13.6\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(-0.056\ \text{m}) = \boxed{9.7\times10^4\ \text{N/m}^2}$$

23. 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.

$$F_{\text{buoyant}} = m_{\text{Fe}}g \quad \rightarrow \quad \rho_{\text{Hg}}gV_{\text{submerged}} = \rho_{\text{Fe}}gV_{\text{total}} \quad \rightarrow$$

$$\frac{V_{\text{submerged}}}{V_{\text{total}}} = \frac{\rho_{\text{Fe}}}{\rho_{\text{Hg}}} = \frac{7.8\times10^3\ \text{kg/m}^3}{13.6\times10^3\ \text{kg/m}^3} = \boxed{0.57} \approx 57\%$$

24. The difference between 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.

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

$$\rho_{\text{rock}} = \rho_{\text{water}}\frac{m_{\text{rock}}}{\Delta m} = (1.00\times10^3\ \text{kg/m}^3)\frac{9.28\ \text{kg}}{9.28\ \text{kg} - 6.18\ \text{kg}} = \boxed{2990\ \text{kg/m}^3}$$

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

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

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

$$= (1.8\times10^4\ \text{kg})(9.80\ \text{m/s}^2)\left(1 - \frac{1.00\times10^3\ \text{kg/m}^3}{7.8\times10^3\ \text{kg/m}^3}\right) = 1.538\times10^5\ \text{N} \approx \boxed{1.5\times10^5\ \text{N}}$$

(*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.

$$T = mg = (1.8\times10^4\ \text{kg})(9.80\ \text{m/s}^2) = 1.764\times10^5\ \text{N} \approx \boxed{1.8\times10^5\ \text{N}}$$

26. 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.

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

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

$$= (1.29\ \text{kg/m}^3 - 0.179\ \text{kg/m}^3)\tfrac{4}{3}\pi(7.15\ \text{m})^3 - 930\ \text{kg} = \boxed{770\ \text{kg}} = 7600\ \text{N}$$

$\boxed{27.}$ The apparent weight is the actual weight minus the buoyant force, as shown in Example 10–8.The buoyant force is the weight of a mass of water occupying the volume of the metal sample.

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

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

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

Based on the density, the metal is probably $\boxed{\text{iron or steel}}$.

28. The difference between 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.

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

$$m_{\text{actual}} = \frac{m_{\text{apparent}}}{1 - \frac{\rho_{\text{air}}}{\rho_{\text{Al}}}} = \frac{4.0000\ \text{kg}}{1 - \frac{1.29\ \text{kg/m}^3}{2.70\times10^3\ \text{kg/m}^3}} = \boxed{4.0019\ \text{kg}}$$

29. The buoyant force on the drum must be equal to the weight of the steel plus the weight of the gasoline. The weight of each component is its respective volume times the density. The buoyant force is the weight of total volume of displaced water. We assume that the drum just barely floats—in other words, the volume of water displaced is equal to the total volume of gasoline and steel.

$$F_B = W_{steel} + W_{gasoline} \rightarrow (V_{gasoline} + V_{steel})\rho_{water}g = V_{steel}\rho_{steel}g + V_{gasoline}\rho_{gasoline}g \rightarrow$$

$$V_{gasoline}\rho_{water} + V_{steel}\rho_{water} = V_{steel}\rho_{steel} + V_{gasoline}\rho_{gasoline} \rightarrow$$

$$V_{steel} = V_{gasoline}\left(\frac{\rho_{water} - \rho_{gasoline}}{\rho_{steel} - \rho_{water}}\right) = (210\text{ L})\left(\frac{1000\text{ kg/m}^3 - 680\text{ kg/m}^3}{7800\text{ kg/m}^3 - 1000\text{ kg/m}^3}\right) = 9.882\text{ L} \approx \boxed{9.9\times 10^{-3}\text{ m}^3}$$

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

$$F_{buoyant} = m_{\substack{water\\displaced}}\,g = \rho_{water}V_{displaced}\,g$$

$$= (1.025\times 10^3\text{ kg/m}^3)(69.6\text{ L})\left(\frac{1\times 10^{-3}\text{ m}^3}{1\text{ L}}\right)(9.80\text{ m/s}^2) = \boxed{699\text{ N}}$$

(*b*) The weight of the diver is $m_{diver}g = (72.8\text{ kg})(9.80\text{ m/s}^2) = 713\text{ N}$. Since the buoyant force is not as large as her weight, $\boxed{\text{she will sink}}$, although she will do so very gradually since the two forces are almost the same.

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

$$F_{buoyant} = W_{ice} \rightarrow m_{\substack{seawater\\submerged}}\,g = m_{ice}g \rightarrow m_{\substack{seawater\\submerged}} = m_{ice} \rightarrow \rho_{seawater}V_{seawater} = \rho_{ice}V_{ice} \rightarrow$$

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

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

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

32. (*a*) The difference between 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.

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

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

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

33. The buoyancy force due to the submerged empty soda bottles must equal the weight of the child. To find the minimum number of bottles (N), we assume that each bottle is completely submerged, so displaces 1.0 L of water.

$$F_{\text{buoyant}} = NV_{\text{bottle}}\rho_{\text{water}}g = m_{\text{child}}g \quad \rightarrow$$

$$N = \frac{m_{\text{child}}}{V_{\text{bottle}}\rho_{\text{water}}} = \frac{32\text{ kg}}{(1.0\text{ L})\left(\frac{10^{-3}\text{ m}^3}{1\text{ L}}\right)(1000\text{ kg/m}^3)} = \boxed{32\text{ bottles}}$$

34. Use the definition of density and specific gravity, and then solve for the fat fraction, f.

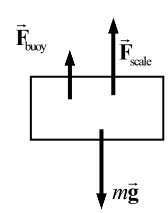
$$m_{\text{fat}} = mf = V_{\text{fat}}\rho_{\text{fat}}; \quad m_{\substack{\text{fat}\\\text{free}}} = m(1-f) = V_{\substack{\text{fat}\\\text{free}}}\rho_{\substack{\text{fat}\\\text{free}}}$$

$$\rho_{\text{body}} = X\rho_{\text{water}} = \frac{m_{\text{total}}}{V_{\text{total}}} = \frac{m_{\text{fat}} + m_{\substack{\text{fat}\\\text{free}}}}{V_{\text{fat}} + V_{\substack{\text{fat}\\\text{free}}}} = \frac{m}{\frac{mf}{\rho_{\text{fat}}} + \frac{m(1-f)}{\rho_{\substack{\text{fat}\\\text{free}}}}} = \frac{1}{\frac{f}{\rho_{\text{fat}}} + \frac{(1-f)}{\rho_{\substack{\text{fat}\\\text{free}}}}} \quad \rightarrow$$

$$f = \frac{\rho_{\text{fat}}\rho_{\substack{\text{fat}\\\text{free}}}}{X\rho_{\text{water}}(\rho_{\substack{\text{fat}\\\text{free}}} - \rho_{\text{fat}})} - \frac{\rho_{\text{fat}}}{(\rho_{\substack{\text{fat}\\\text{free}}} - \rho_{\text{fat}})} = \frac{(0.90\text{ g/cm}^3)(1.10\text{ g/cm}^3)}{X(1.0\text{ g/cm}^3)(0.20\text{ g/cm}^3)} - \frac{(0.90\text{ g/cm}^3)}{(0.20\text{ g/cm}^3)}$$

$$= \frac{4.95}{X} - 4.5 \quad \rightarrow \quad \%\text{ Body fat} = 100f = 100\left(\frac{4.95}{X} - 4.5\right) = \boxed{\frac{495}{X} - 450}$$

35. (*a*) The free-body diagram for the athlete shows three forces—the athlete's weight, the buoyancy force, and the upward force of the scale. Those forces must add to give 0, and that can be used to find the volume of the athlete.



$$F_{\text{buoyant}} + F_{\text{scale}} - F_{\text{weight}} = \rho_{\text{water}}Vg + m_{\text{apparant}}g - m_{\text{actual}}g = 0 \quad \rightarrow$$

$$V = \frac{m_{\text{actual}} - m_{\text{apparant}}}{\rho_{\text{water}}} = \frac{70.2\text{ kg} - 3.4\text{ kg}}{1000\text{ kg/m}^3} = \boxed{6.68\times 10^{-2}\text{ m}^3}$$

(*b*) The specific gravity is the athlete's density divided by the density of water.

$$\text{SG} = \frac{\rho_{\text{athlete}}}{\rho_{\text{water}}} = \frac{m/(V - V_{\text{R}})}{\rho_{\text{water}}} = \frac{(70.2\text{ kg})/(6.68\times 10^{-2}\text{ m}^3 - 1.3\times 10^{-3}\text{ m}^3)}{1000\text{ kg/m}^3} = 1.072 \approx \boxed{1.07}$$

(*c*) We use the formula given with the problem.

$$\%\text{ Body fat} = \frac{495}{\text{SG}} - 450 = \frac{495}{1.072} - 450 = \boxed{12\%}$$

36. 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.

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

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

$$m_{\text{Pb}} = m_{\text{wood}}\frac{\left(\frac{\rho_{\text{water}}}{\rho_{\text{wood}}} - 1\right)}{\left(1 - \frac{\rho_{\text{water}}}{\rho_{\text{Pb}}}\right)} = m_{\text{wood}}\frac{\left(\frac{1}{\text{SG}_{\text{wood}}} - 1\right)}{\left(1 - \frac{1}{\text{SG}_{\text{Pb}}}\right)} = (3.65\text{ kg})\frac{\left(\frac{1}{0.50} - 1\right)}{\left(1 - \frac{1}{11.3}\right)} = \boxed{4.00\text{ kg}}$$

37. We apply the equation of continuity at constant density, Eq. 10–4b. The flow rate out of the duct must be equal to the flow rate into the room.

$$A_{\text{duct}}\upsilon_{\text{duct}} = \pi r^2\upsilon_{\text{duct}} = \frac{V_{\text{room}}}{t_{\text{to fill room}}} \rightarrow \upsilon_{\text{duct}} = \frac{V_{\text{room}}}{\pi r^2 t_{\text{to fill room}}} = \frac{(8.2\text{ m})(5.0\text{ m})(3.5\text{ m})}{\pi(0.12\text{ m})^2(12\text{ min})\left(\frac{60\text{ s}}{1\text{ min}}\right)} = \boxed{4.4\text{ m/s}}$$

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

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

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

39. We may apply Torricelli's theorem, Eq. 10–6.

$$\upsilon_1 = \sqrt{2g(y_2 - y_1)} = \sqrt{2(9.80\text{ m/s}^2)(4.7\text{ m})} = \boxed{9.6\text{ m/s}}$$

40. Bernoulli's equation is evaluated with $\upsilon_1 = \upsilon_2 = 0.$ Let point 1 be the initial point and point 2 be the final point.

$$P_1 + \tfrac{1}{2}\rho\upsilon_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho\upsilon_2^2 + \rho g y_2 \rightarrow P_1 + \rho g y_1 = P_2 + \rho g y_2 \rightarrow$$

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

But a change in the y coordinate is the opposite of the change in depth, which is what is represented in Eq. 10–3b. So our final result is $\Delta P = \rho_0 g \Delta h,$ Eq. 10–3b.

41. The pressure head can be interpreted as an initial height for the water, with a speed of 0 and at 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.

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

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

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

$$\text{Volume flow rate} = A\upsilon = \pi r^2 \sqrt{2gy_{\text{head}}} = \pi \left[\tfrac{1}{2}(1.85 \times 10^{-2}\,\text{m})\right]^2 \sqrt{2(9.80\,\text{m/s}^2)(12.0\,\text{m})}$$

$$= \boxed{4.12 \times 10^{-3}\ \text{m}^3/\text{s}}$$

42. The flow speed is the speed of the water in the input tube. The entire volume of the water in the tank is to be processed in 4.0 h. The volume of water passing through the input tube per unit time is the volume rate of flow, as expressed in the text in the paragraph following Eq. 10–4b.

$$\frac{V}{\Delta t} = A\upsilon \quad \rightarrow \quad \upsilon = \frac{V}{A\Delta t} = \frac{\ell wh}{\pi r^2 \Delta t} = \frac{(0.36\text{ m})(1.0\text{ m})(0.60\text{ m})}{\pi(0.015\text{ m})^2(3.0\text{ h})\left(\dfrac{3600\text{ s}}{1\text{ h}}\right)} = 0.02829\text{ m/s} \approx \boxed{2.8\text{ cm/s}}$$

43. 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.

$$P_1 + \tfrac{1}{2}\rho \upsilon_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho \upsilon_2^2 + \rho g y_2 \rightarrow$$

$$P_1 - P_{\text{atm}} = \rho g y_2 = (1.00 \times 10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(16\text{ m}) = \boxed{1.6 \times 10^5\text{ N/m}^2}$$

44. 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.

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

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

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

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

45. Use the equation of continuity (Eq. 10–4b) 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. 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.

$$A_1\upsilon_1 = A_2\upsilon_2 \rightarrow \upsilon_2 = \upsilon_1 \frac{A_1}{A_2} = \upsilon_1 \frac{\pi r_1^2}{\pi r_2^2} = \upsilon_1 \frac{r_1^2}{r_2^2}$$

$$P_0 + P_1 + \tfrac{1}{2}\rho\upsilon_1^2 + \rho g y_1 = P_0 + P_2 + \tfrac{1}{2}\rho\upsilon_2^2 + \rho g y_2 \rightarrow$$

$$P_1 + \tfrac{1}{2}\rho\upsilon_1^2 = P_2 + \tfrac{1}{2}\rho\upsilon_2^2 = P_2 + \tfrac{1}{2}\rho\upsilon_1^2 \frac{r_1^4}{r_2^4} \rightarrow \upsilon_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho\left(\frac{r_1^4}{r_2^4} - 1\right)}} \rightarrow$$

$$A_1\upsilon_1 = \pi r_1^2 \sqrt{\frac{2(P_1 - P_2)}{\rho\left(\frac{r_1^4}{r_2^4} - 1\right)}} = \pi(3.0\times10^{-2}\ \text{m})^2 \sqrt{\frac{2(33.5\times10^3\ \text{Pa} - 22.6\times10^3\ \text{Pa})}{(1.00\times10^3\ \text{kg/m}^3)\left(\frac{(3.0\times10^{-2}\ \text{m})^4}{(2.25\times10^{-2}\ \text{m})^4} - 1\right)}}$$

$$= \boxed{9.0\times10^{-3}\ \text{m}^3/\text{s}}$$

46. The air pressure inside the hurricane can be estimated by using Bernoulli's equation, Eq. 10–5. Assume that the pressure outside the hurricane is atmospheric pressure, the speed of the wind outside the hurricane is 0, and the two pressure measurements are made at the same height.

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

$$P_{\text{inside}} = P_{\text{outside}} - \tfrac{1}{2}\rho_{\text{air}}\upsilon_{\text{inside}}^2$$

$$= 1.013\times10^5\ \text{Pa} - \tfrac{1}{2}\left(1.29\ \text{kg/m}^3\right)\left[(300\ \text{km/h})\left(\frac{1000\ \text{m}}{\text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\right]^2$$

$$= \boxed{9.7\times10^4\ \text{Pa}} \approx 0.96\ \text{atm}$$

47. 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, Eq. 10–5. 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.

$$P_1 + \tfrac{1}{2}\rho\upsilon_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho\upsilon_2^2 + \rho g y_2 \rightarrow P_1 - P_2 = \tfrac{1}{2}\rho(\upsilon_2^2 - \upsilon_1^2)$$

$$F_{\text{lift}} = (P_1 - P_2)(\text{Area of wing}) = \tfrac{1}{2}\rho\left(\upsilon_2^2 - \upsilon_1^2\right)A$$

$$= \tfrac{1}{2}(1.29\ \text{kg/m}^3)[(280\ \text{m/s})^2 - (150\ \text{m/s})^2](88\ \text{m}^2) = \boxed{3.2\times10^6\ \text{N}}$$

48. Use the equation of continuity (Eq. 10–4b) 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 pressure as atmospheric pressure plus gauge pressure.

$$A_{\text{street}}\upsilon_{\text{street}} = A_{\text{top}}\upsilon_{\text{top}} \quad \rightarrow$$

$$\upsilon_{\text{top}} = \upsilon_{\text{street}}\frac{A_{\text{street}}}{A_{\text{top}}} = (0.78\text{ m/s})\frac{\pi\left[\frac{1}{2}(5.0\times10^{-2}\text{ m})\right]^2}{\pi\left[\frac{1}{2}(2.8\times10^{-2}\text{ m})\right]^2} = 2.487\text{ m/s} \approx \boxed{2.5\text{ m/s}}$$

$$P_0 + P_{\substack{\text{gauge}\\\text{street}}} + \tfrac{1}{2}\rho\upsilon_{\text{street}}^2 + \rho g y_{\text{street}} = P_0 + P_{\substack{\text{gauge}\\\text{top}}} + \tfrac{1}{2}\rho\upsilon_{\text{top}}^2 + \rho g y_{\text{top}} \quad \rightarrow$$

$$P_{\substack{\text{gauge}\\\text{top}}} = P_{\substack{\text{gauge}\\\text{street}}} + \tfrac{1}{2}\rho\left(\upsilon_{\text{street}}^2 - \upsilon_{\text{top}}^2\right) + \rho g(y_{\text{street}} - y_{\text{top}})$$

$$= (3.8\text{ atm})\left(\frac{1.013\times10^5\text{ Pa}}{\text{atm}}\right) + \tfrac{1}{2}(1.00\times10^3\text{ kg/m}^3)\left[(0.78\text{ m/s})^2 - (2.487\text{ m/s})^2\right]^2$$

$$+ (1.00\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(-16\text{ m})$$

$$= 2.250\times10^5\text{ Pa}\left(\frac{1\text{ atm}}{1.013\times10^5\text{ Pa}}\right) \approx \boxed{2.2\text{ atm}}$$

49. Consider the volume of fluid in the pipe. At each end of the pipe there is a force toward the contained fluid, given by $F = PA.$ Since the area of the pipe is constant, we have $F_{\text{net}} = (P_1 - P_2)A.$ Then, since the power required is the force on the fluid times its velocity, and $AV = Q$ = volume rate of flow, we have $\text{power} = F_{\text{net}}\upsilon = (P_1 - P_2)A\upsilon = \boxed{(P_1 - P_2)Q}.$

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

$$A_2\upsilon_2 = A_1\upsilon_1 \quad \rightarrow \quad \upsilon_2 = \upsilon_1\frac{A_1}{A_2};\quad P_1 + \tfrac{1}{2}\rho\upsilon_1^2 = P_2 + \tfrac{1}{2}\rho\upsilon_2^2 \quad \rightarrow \quad \frac{2(P_1 - P_2)}{\rho} = \upsilon_2^2 - \upsilon_1^2 \quad \rightarrow$$

$$\left(\upsilon_1\frac{A_1}{A_2}\right)^2 - \upsilon_1^2 = \frac{2(P_1 - P_2)}{\rho} \quad \rightarrow \quad \upsilon_1^2\left(\frac{A_1^2}{A_2^2} - \frac{A_2^2}{A_2^2}\right) = \frac{2(P_1 - P_2)}{\rho} \quad \rightarrow$$

$$\upsilon_1^2 = \frac{2A_2^2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)} \quad \rightarrow \quad \boxed{\upsilon_1 = A_2\sqrt{\frac{2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)}}}$$

(*b*) $\upsilon_1 = A_2\sqrt{\dfrac{2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)}}$

$$= \pi\left[\tfrac{1}{2}(0.010\text{ m})\right]^2\sqrt{\frac{2(18\text{ mm-Hg})\left(\dfrac{133\text{ N/m}^2}{\text{mm-Hg}}\right)}{(1000\text{ kg/m}^3)\left(\pi^2\left[\frac{1}{2}(0.035\text{ m})\right]^4 - \pi^2\left[\frac{1}{2}(0.010\text{ m})\right]^4\right)}} = \boxed{0.18\text{ m/s}}$$

51. There is a forward force on the exiting water, so by Newton's third law there is an equal force pushing backward on the hose. To keep the hose stationary, you push forward on the hose, so the hose pushes backward on you. So the force on the exiting water is the same magnitude as the force on the person holding the hose. Use Newton's second law and the equation of continuity to find the force. Note that the 450 L/min flow rate is the volume of water being accelerated per unit time. Also, the flow rate is the product of the cross-sectional area of the moving fluid and the speed of the fluid, so $V/t = A_1\upsilon_1 = A_2\upsilon_2.$

$$F = m\frac{\Delta \upsilon}{\Delta t} = m\frac{\upsilon_2 - \upsilon_1}{t} = \rho\left(\frac{V}{t}\right)(\upsilon_2 - \upsilon_1) = \rho\left(\frac{V}{t}\right)\left(\frac{A_2\upsilon_2}{A_2} - \frac{A_1\upsilon_1}{A_1}\right) = \rho\left(\frac{V}{t}\right)^2\left(\frac{1}{A_2} - \frac{1}{A_1}\right)$$

$$= \rho\left(\frac{V}{t}\right)^2\left(\frac{1}{\pi r_2^2} - \frac{1}{\pi r_1^2}\right)$$

$$= \left(1.00\times 10^3\ \frac{\text{kg}}{\text{m}^3}\right)\left(\frac{420\ \text{L}}{\text{min}}\times\frac{1\ \text{min}}{60\ \text{s}}\times\frac{1\ \text{m}^3}{1000\ \text{L}}\right)^2\frac{1}{\pi}\left(\frac{1}{\left[\frac{1}{2}(0.75\times 10^{-2}\ \text{m})\right]^2} - \frac{1}{\left[\frac{1}{2}(7.0\times 10^{-2}\ \text{m})\right]^2}\right)$$

$$= 1103\ \text{N} \approx \boxed{1100\ \text{N}}$$

52. Apply Eq. 10–8 for the viscosity force. Use the average radius to calculate the plate area.

$$F = \eta A\frac{\upsilon}{\ell} \quad\rightarrow\quad \eta = \frac{F\ell}{A\upsilon} = \frac{\left(\frac{\tau}{r_{\text{inner}}}\right)(r_{\text{outer}} - r_{\text{inner}})}{(2\pi r_{\text{avg}}h)(\omega r_{\text{inner}})}$$

$$= \frac{\left(\frac{0.024\ \text{m}\cdot\text{N}}{0.0510\ \text{m}}\right)(0.20\times 10^{-2}\ \text{m})}{2\pi(0.0520\ \text{m})(0.120\ \text{m})\left(57\ \frac{\text{rev}}{\text{min}}\times\frac{2\pi\ \text{rad}}{\text{rev}}\times\frac{1\ \text{min}}{60\ \text{s}}\right)(0.0510\ \text{m})} = \boxed{7.9\times 10^{-2}\ \text{Pa}\cdot\text{s}}$$

53. Use Poiseuille's equation (Eq. 10–9) to find the pressure difference.

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

$$(P_2 - P_1) = \frac{8\left[6.2\times 10^{-3}\ \frac{\text{L}}{\text{min}}\left(\frac{1\ \text{min}}{60\ \text{s}}\right)\left(\frac{10^{-3}\ \text{m}^3}{\text{L}}\right)\right](0.2\ \text{Pa}\cdot\text{s})(0.102\ \text{m})}{\pi\left[\frac{1}{2}(1.8\times 10^{-3}\ \text{m})\right]^4} = \boxed{8200\ \text{Pa}}$$

54. From Poiseuille's equation, Eq. 10–9, the volume flow rate Q is proportional to R^4 if all other factors are the same. Thus $\frac{Q}{R^4} = \frac{V}{t}\frac{1}{R^4}$ is constant. If the volume of water used to water the garden is to be same in both cases, then tR^4 is constant.

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

Thus the $\boxed{\text{time has been cut by 87\%}}$.

55. Use Poiseuille's equation, Eq. 10–9, to find the radius, and then double the radius to find the diameter.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta\ell} \quad \rightarrow \quad d = 2R = 2\left[\frac{8\eta\ell Q}{\pi(P_2 - P_1)}\right]^{1/4} \rightarrow$$

$$d = 2\left[\frac{8(1.8\times10^{-5}\ \text{Pa}\cdot\text{s})(15.5\ \text{m})\left(\frac{(8.0\ \text{m})(14.0\ \text{m})(4.0\ \text{m})}{900\ \text{s}}\right)}{\pi(0.710\times10^{-3}\ \text{atm})(1.013\times10^{5}\ \text{Pa/atm})}\right]^{1/4} = \boxed{0.094\ \text{m}}$$

56. Use Poiseuille's equation, Eq. 10–9, to find the pressure difference.

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

$$(P_2 - P_1) = \frac{8Q\eta\ell}{\pi R^4} = \frac{8(650\ \text{cm}^3/\text{s})(10^{-6}\ \text{m}^3/\text{cm}^3)(0.20\ \text{Pa}\cdot\text{s})(1600\ \text{m})}{\pi(0.145\ \text{m})^4}$$

$$= 1198\ \text{Pa} \approx \boxed{1200\ \text{Pa}}$$

57. (*a*) We calculate the Reynolds number with the given formula.

$$Re = \frac{2\bar{v}r\rho}{\eta} = \frac{2(0.35\ \text{m/s})(0.80\times10^{-2}\ \text{m})(1.05\times10^{3}\ \text{kg/m}^3)}{4\times10^{-3}\ \text{Pa}\cdot\text{s}} = 1470$$

The flow is **laminar** at this speed.

(*b*) Doubling the velocity doubles the Reynolds number, to 2940. The flow is now **turbulent**.

58. From Poiseuille's equation, Eq. 10–9, the volume flow rate Q is proportional to R^4 if all other factors are the same. Thus, Q/R^4 is constant.

$$\frac{Q_{\text{final}}}{R^4_{\text{final}}} = \frac{Q_{\text{initial}}}{R^4_{\text{initial}}} \quad \rightarrow \quad R_{\text{final}} = \left(\frac{Q_{\text{final}}}{Q_{\text{initial}}}\right)^{1/4} R_{\text{initial}} = (0.35)^{1/4} R_{\text{initial}} = 0.769 R_{\text{initial}}$$

The radius has been reduced by about **23%**.

59. The pressure drop per cm can be found from Poiseuille's equation, Eq. 10–9, using a length of 1 cm. The volume flow rate is the area of the aorta times the speed of the moving blood.

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

$$\frac{(P_2 - P_1)}{\ell} = \frac{8\eta Q}{\pi R^4} = \frac{8\eta\pi R^2 v}{\pi R^4} = \frac{8\eta v}{R^2} = \frac{8(4\times10^{-3}\ \text{Pa}\cdot\text{s})(0.4\ \text{m/s})}{(1.2\times10^{-2}\ \text{m})^2} = 88.9\ \text{Pa/m} = \boxed{0.89\ \text{Pa/cm}}$$

60. The fluid pressure must be 78 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 78 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. 10–3c to find the height of the blood reservoir necessary to produce that excess pressure.

$$Q=\frac{\pi R^4(P_2-P_1)}{8\eta_{\text{blood}}\ell} \rightarrow P_2=P_1+\frac{8\eta_{\text{blood}}\ell Q}{\pi R^4}=\rho_{\text{blood}}g\Delta h \rightarrow \Delta h=\frac{1}{\rho_{\text{blood}}g}\left(P_1+\frac{8\eta_{\text{blood}}\ell Q}{\pi R^4}\right)$$

$$\Delta h=\frac{1}{\left(1050\ \frac{\text{kg}}{\text{m}^3}\right)(9.80\ \text{m/s}^2)}\left(\begin{array}{c}(78\ \text{mm-Hg})\left(\frac{133\ \text{N/m}^2}{1\ \text{mm-Hg}}\right)+ \\ \frac{8(4\times10^{-3}\ \text{Pa}\cdot\text{s})(0.025\ \text{m})\left(\frac{2.0\times10^{-6}\ \text{m}^3}{60\ \text{s}}\right)}{\pi(0.4\times10^{-3}\ \text{m})^4}\end{array}\right)=1.04\ \text{m}\approx\boxed{1.0\ \text{m}}$$

61. In Fig. 10–34, we have $\gamma=F/2\ell$. Use this to calculate the surface tension.

$$\gamma=\frac{F}{2\ell}=\frac{3.4\times10^{-3}\ \text{N}}{2(0.070\ \text{m})}=\boxed{2.4\times10^{-2}\ \text{N/m}}$$

62. As in Fig. 10–34, there are two surfaces being increased, so $\gamma=F/2\ell$. Use this to calculate the force.

$$\gamma=F/2\ell \rightarrow F=2\gamma\ell=2(0.025\ \text{N/m})(0.215\ \text{m})=\boxed{1.1\times10^{-2}\ \text{N}}$$

63. (*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 Fig. 10–36 (b). Thus, $\boxed{\gamma=\frac{F}{2(2\pi r)}=\frac{F}{4\pi r}}$.

(*b*) $$\gamma=\frac{F}{4\pi r}=\frac{6.20\times10^{-3}\ \text{N}}{4\pi(2.9\times10^{-2}\ \text{m})}=\boxed{1.7\times10^{-2}\ \text{N/m}}$$

64. From Example 10–15, we have $2\pi r\gamma\cos\theta=\frac{1}{6}mg$. The maximum mass will occur at $\theta=0°$.

$$2\pi r\gamma\cos\theta=\tfrac{1}{6}mg \rightarrow m_{\text{max}}=\frac{12\pi r\gamma}{g}=\frac{12\pi(3.0\times10^{-5}\ \text{m})(0.072\ \text{N/m})}{9.80\ \text{m/s}^2}=8.3\times10^{-6}\ \text{kg}$$

This is much less than the insect's mass, so $\boxed{\text{the insect will not remain on top of the water}}$.

65. As an estimate, we assume that the surface tension force acts vertically. We assume that the free-body diagram for the cylinder is similar to Fig. 10–36a. The weight must equal the total surface tension force. The needle is of length ℓ.

$$mg=2F_{\text{T}} \rightarrow \rho_{\text{needle}}\pi\left(\tfrac{1}{2}d_{\text{needle}}\right)^2\ell g=2\gamma\ell \rightarrow$$

$$d_{\text{needle}}=\sqrt{\frac{8\gamma}{\rho_{\text{needle}}\pi g}}=\sqrt{\frac{8(0.072\ \text{N/m})}{(7800\ \text{kg/m}^3)\pi(9.80\ \text{m/s}^2)}}=1.55\times10^{-3}\ \text{m}\approx\boxed{1.5\ \text{mm}}$$

66. The difference in pressure from the heart to the calf is given by Eq. 10–3b.

$$\Delta P = \rho g \Delta h = (1.05\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(1\ \text{m}) = 1.029\times10^4\ \text{Pa} \approx \boxed{1\times10^4\ \text{Pa}}$$

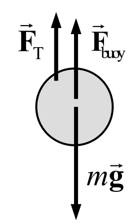
67. (*a*) The fluid in the needle is confined, so Pascal's principle may be applied.

$$P_{\text{plunger}} = P_{\text{needle}} \rightarrow \frac{F_{\text{plunger}}}{A_{\text{plunger}}} = \frac{F_{\text{needle}}}{A_{\text{needle}}} \rightarrow F_{\text{needle}} = F_{\text{plunger}}\frac{A_{\text{needle}}}{A_{\text{plunger}}} = F_{\text{plunger}}\frac{\pi r_{\text{needle}}^2}{\pi r_{\text{plunger}}^2}$$

$$= F_{\text{plunger}}\frac{r_{\text{needle}}^2}{r_{\text{plunger}}^2} = (3.2\ \text{N})\frac{(0.10\times10^{-3}\ \text{m})^2}{(0.65\times10^{-2}\ \text{m})^2} = \boxed{7.6\times10^{-4}\ \text{N}}$$

(*b*) $$F_{\text{plunger}} = P_{\text{plunger}}A_{\text{plunger}} = (75\ \text{mm-Hg})\left(\frac{133\ \text{N/m}^2}{1\ \text{mm-Hg}}\right)\pi(0.65\times10^{-2}\ \text{m})^2 = \boxed{1.3\ \text{N}}$$

68. The ball has three vertical forces on it: string tension, buoyant force, and gravity. See the free-body diagram for the ball. The net force must be 0.



$$F_{\text{net}} = F_{\text{T}} + F_{\text{buoy}} - mg = 0 \rightarrow$$

$$F_{\text{T}} = mg - F_{\text{buoy}} = \tfrac{4}{3}\pi r^3\rho_{\text{Cu}}g - \tfrac{4}{3}\pi r^3\rho_{\text{water}}g = \tfrac{4}{3}\pi r^3 g(\rho_{\text{Cu}} - \rho_{\text{water}})$$

$$= \tfrac{4}{3}\pi(0.013\ \text{m})^3(9.80\ \text{m/s}^2)(8900\ \text{kg/m}^3 - 1000\ \text{kg/m}^3) = 0.7125\ \text{N} \approx \boxed{0.71\ \text{N}}$$

Since the water pushes up on the ball via the buoyant force, there is a downward force on the water due to the ball, equal in magnitude to the buoyant force. That mass equivalent of that force (indicated by $m_{\text{B}} = F_{\text{B}}/g$) will show up as an increase in the balance reading.

$$F_{\text{B}} = \tfrac{4}{3}\pi r^3\rho_{\text{water}}g \rightarrow$$

$$m_{\text{B}} = \frac{F_{\text{B}}}{g} = \tfrac{4}{3}\pi r^3\rho_{\text{water}} = \tfrac{4}{3}\pi(0.013\ \text{m})^3(1000\ \text{kg/m}^3) = 9.203\times10^{-3}\ \text{kg} = 9.203\ \text{g}$$

$$\text{Balance reading} = 975.0\ \text{g} + 9.2\ \text{g} = \boxed{984.2\ \text{g}}$$

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

$$\Delta P = \rho g \Delta h \rightarrow \frac{\Delta P}{P_0} = \frac{\rho g \Delta h}{P_0} = \frac{(1.29\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(380\ \text{m})}{1.013\times10^5\ \text{Pa}} = 0.047 \rightarrow$$

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

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

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

$$A_{\text{input}} = A_{\text{output}} \frac{F_{\text{input}}}{F_{\text{output}}} = \pi(9.0\times10^{-2}\text{ m})^2 \frac{380\text{ N}}{(960\text{ kg})(9.80\text{ m/s}^2)} = 1.028\times10^{-3}\text{ m}^2$$

$$\approx \boxed{1.0\times10^{-3}\text{ m}^2}$$

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

$$W = mgh = (960\text{ kg})(9.80\text{ m/s}^2)(0.42\text{ m}) = 3951\text{ J} \approx \boxed{4.0\times10^3\text{ J}}$$

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

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

$$h = \frac{F_{\text{input}} d_{\text{input}}}{mg} = \frac{(380\text{ N})(0.13\text{ m})}{(960\text{ kg})(9.80\text{ m/s}^2)} = 5.251\times10^{-3}\text{ m} \approx \boxed{5.3\times10^{-3}\text{ m}}$$

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

$$h_{\text{full}} = N h_{\text{stroke}} \quad \rightarrow \quad N = \frac{h_{\text{full}}}{h_{\text{stroke}}} = \frac{0.42\text{ m}}{5.251\times10^{-3}\text{ m}} = \boxed{80\text{ strokes}}$$

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

$$W_{\text{input}} = N F_{\text{input}} d_{\text{input}} \quad \rightarrow \quad 80(380\text{ N})(0.13\text{ m}) = 3952\text{ J} \approx \boxed{4.0\times10^3\text{ J}}$$

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

71. 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.

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

$$F = \rho g \Delta h A = (1.29\text{ kg/m}^3)(9.80\text{ m/s}^2)(1250\text{ m})(0.20\times10^{-4}\text{ m}^2) = 0.3161\text{ N} \approx \boxed{0.32\text{ N}}$$

72. The change in pressure with height is given by Eq. 10–3b.

$$\Delta P = \rho g \Delta h \quad \rightarrow \quad \frac{\Delta P}{P_0} = \frac{\rho g \Delta h}{P_0} = \frac{(1.05\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(6\text{ m})}{1.013\times10^5\text{ Pa}} = 0.609 \quad \rightarrow$$

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

73. The pressure head can be interpreted as an initial height for the water, with a speed of 0 and at 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.

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

$$y_{\text{head}} = \frac{v_{\text{faucet}}^2}{2g} = \frac{(9.2\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = \boxed{4.3\text{ m}}$$

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

$$\Delta P = \rho g \Delta h \quad \rightarrow \quad \Delta h = \frac{\Delta P}{\rho g} = \frac{(75 \text{ mm-Hg})\left(\dfrac{133 \text{ N/m}^2}{1 \text{ mm-Hg}}\right)}{(1.00\times10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = 1.018 \text{ m} \approx \boxed{1.0 \text{ m}}$$

75. The force can be found by multiplying the pressure and the area of the pump cylinder.

$$F_{\text{i}} = P_{\text{i}}A = (2.10\times10^5 \text{ N/m}^2)\pi(0.0125 \text{ m})^2 = 1.0\times10^2 \text{ N}$$
$$F_{\text{f}} = P_{\text{f}}A = (3.10\times10^5 \text{ N/m}^2)\pi(0.0125 \text{ m})^2 = 1.5\times10^2 \text{ N}$$

The range of forces is $\boxed{100 \text{ N} \le F \le 150 \text{ N}}$.

76. 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.

$$P = \frac{F}{A} = \frac{mg}{V/d} = \frac{mgd}{V} = \frac{mgd}{m/\rho} = gd\rho = (9.80 \text{ m/s}^2)(2000 \text{ m})(917 \text{ kg/m}^3) = 1.80\times10^7 \text{ Pa}$$
$$\approx \boxed{2\times10^7 \text{ Pa}}$$

77. 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.

$$W_{\text{continent}} = W_{\substack{\text{displaced}\\\text{mantle}}} \quad \rightarrow \quad Ah\rho_{\text{continent}}g = A(h-y)\rho_{\text{mantle}}g \quad \rightarrow$$
$$y = h\left(1 - \frac{\rho_{\text{continent}}}{\rho_{\text{mantle}}}\right) = (35 \text{ km})\left(1 - \frac{2800 \text{ kg/m}^3}{3300 \text{ kg/m}^3}\right) = \boxed{5.3 \text{ km}}$$

78. The "extra" buoyant force on the ship, due to the loaded fresh water, is the weight of "extra" displaced seawater, as indicated by the ship floating lower in the sea. This buoyant force is given by $F_{\text{buoyant}} = V_{\text{displaced}}\rho_{\substack{\text{sea}\\\text{water}}}g$. But this extra buoyant force is what holds up the fresh water, so that force must also be equal to the weight of the fresh water.

$$F_{\text{buoyant}} = V_{\text{displaced}}\rho_{\substack{\text{sea}\\\text{water}}}g = m_{\text{fresh}}g \;\rightarrow\; m_{\text{fresh}} = (2240 \text{ m}^2)(8.25 \text{ m})(1025 \text{ kg/m}^3) = \boxed{1.89\times10^7 \text{ kg}}$$

This can also be expressed as a volume.

$$V_{\text{fresh}} = \frac{m_{\text{fresh}}}{\rho_{\text{fresh}}} = \frac{1.89\times10^7 \text{ kg}}{1.00\times10^3 \text{ kg/m}^3} = \boxed{1.89\times10^4 \text{ m}^3} = \boxed{1.89\times10^7 \text{ L}}$$

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. That can be converted to pressure times volume.

$$W = F\Delta\ell = PA\Delta\ell = PV \quad \rightarrow$$

$$\text{Power} = \frac{W}{t} = \frac{PV}{t} = \frac{(105 \text{ mm-Hg})\left(\dfrac{133 \text{ N/m}^2}{1 \text{ mm-Hg}}\right)(70 \times 10^{-6} \text{ m}^3)}{\left(\dfrac{1}{70}\text{min}\right)\left(\dfrac{60 \text{ s}}{\text{min}}\right)} = 1.14 \text{ W} \approx \boxed{1 \text{ W}}$$

80. (*a*) We assume that the water is launched at ground level. Since it also lands at ground level, the level range formula from Chapter 3 may be used.

$$R = \frac{\upsilon_0^2 \sin 2\theta}{g} \rightarrow \upsilon_0 = \sqrt{\frac{Rg}{\sin 2\theta}} = \sqrt{\frac{(6.0 \text{ m})(9.80 \text{ m/s}^2)}{\sin 70^\circ}} = 7.910 \text{ m/s} \approx \boxed{7.9 \text{ m/s}}$$

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

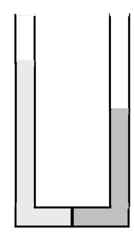
$$\text{Volume flow rate} = A\upsilon = 4\pi r^2 \upsilon = 4\pi(1.5 \times 10^{-3} \text{ m})^2(7.910 \text{ m/s})$$

$$= 2.236 \times 10^{-4} \text{ m}^3/\text{s}\left(\frac{1 \text{ L}}{1.0 \times 10^{-3} \text{ m}^3}\right) \approx \boxed{0.22 \text{ L/s}}$$

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

$$(A\upsilon)_{\text{supply}} = (A\upsilon)_{\text{heads}} \rightarrow \upsilon_{\text{supply}} = \frac{(A\upsilon)_{\text{heads}}}{A_{\text{supply}}} = \frac{2.236 \times 10^{-4} \text{ m}^3/\text{s}}{\pi(0.95 \times 10^{-2} \text{ m})^2} = \boxed{0.79 \text{ m/s}}$$

81. 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.



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

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

$$\Delta h_{\text{water}} = \Delta h_{\text{alcohol}} \frac{\rho_{\text{alcohol}}}{\rho_{\text{water}}} = 16.0 \text{ cm}(0.790) = \boxed{12.6 \text{ cm}}$$

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

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

$\boxed{83.}$ 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.

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

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

$$\upsilon_{\text{top}}^2 = \frac{2(P_{\text{bottom}} - P_{\text{top}})}{\rho} + \upsilon_{\text{bottom}}^2 \quad \rightarrow \quad \upsilon_{\text{top}} = \sqrt{\frac{2(P_{\text{bottom}} - P_{\text{top}})}{\rho} + \upsilon_{\text{bottom}}^2} = \sqrt{\frac{2mg}{\rho A} + \upsilon_{\text{bottom}}^2}$$

$$\upsilon_{\text{top}} = \sqrt{\frac{2(1.7\times10^6\ \text{kg})(9.80\ \text{m/s}^2)}{(1.29\ \text{kg/m}^3)(1200\ \text{m}^2)} + (95\ \text{m/s})^2} = 174.8\ \text{m/s} \approx \boxed{170\ \text{m/s}}$$

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

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

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

$$F_{\text{air}} = \tfrac{1}{2}\rho_{\text{air}}\upsilon_{\text{outside}}^2 A_{\text{roof}} = \tfrac{1}{2}(1.29\ \text{kg/m}^3)\left[(180\ \text{km/h})\left(\frac{1\ \text{m/s}}{3.6\ \text{km/h}}\right)\right]^2 (6.0\ \text{m}^2) = \boxed{9700\ \text{N}}$$

85. 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.

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

$$\eta = \frac{\pi(0.20\times10^{-3}\ \text{m})^4(1.05\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(1.40\ \text{m})}{8\left[4.1\ \frac{\text{cm}^3}{\text{min}}\times\frac{1\ \text{min}}{60\ \text{s}}\times\frac{10^{-6}\ \text{m}^3}{\text{cm}^3}\right](3.8\times10^{-2}\ \text{m})} = \boxed{3.5\times10^{-3}\ \text{Pa}\cdot\text{s}}$$

86. We assume that the water is launched from the same level at which it lands. Then the level range formula, derived in Example 3–10, applies. That formula is $R = \frac{\upsilon_0^2 \sin 2\theta_0}{g}$. If the range has increased by a factor of 4, then the initial speed has increased by a factor of 2. The equation of continuity is then applied to determine the change in the hose opening. The water will have the same volume rate of flow whether the opening is large or small.

$$(A\upsilon)_{\substack{\text{fully}\\\text{open}}} = (A\upsilon)_{\substack{\text{partly}\\\text{open}}} \quad \rightarrow \quad A_{\substack{\text{partly}\\\text{open}}} = A_{\substack{\text{fully}\\\text{open}}} \frac{\upsilon_{\substack{\text{fully}\\\text{open}}}}{\upsilon_{\substack{\text{partly}\\\text{open}}}} = A_{\substack{\text{fully}\\\text{open}}}\left(\frac{1}{2}\right)$$

Thus, $\boxed{1/2}$ of the hose opening was blocked.

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

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

$$m_{\text{Cu}} = m_{\text{wood}}\left(\frac{\rho_{\text{water}}}{\rho_{\text{wood}}} - 1\right) = (0.40\text{ kg})\left(\frac{1000\text{ kg/m}^3}{600\text{ kg/m}^3} - 1\right) = \boxed{0.27\text{ kg}}$$

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 25%, then so is the radius.

$$\frac{Q_{\text{final}}}{R^4_{\text{final}}} = \frac{Q_{\text{initial}}}{R^4_{\text{initial}}} \rightarrow \frac{Q_{\text{final}}}{Q_{\text{initial}}} = \frac{R^4_{\text{final}}}{R^4_{\text{initial}}} = (0.75)^4 = 0.32$$

The flow rate is 32% of the original value.

Solutions to Search and Learn Problems

1. When the block is submerged in the water, the water exerts an upward buoyant force on the block equal to the weight of the water displaced. By Newton's third law, the block then exerts an equal force down on the water. Since the two objects are placed symmetrically about the pivot, they will be balanced when the forces on the two sides of the board are equal.

$$(5.0\text{ kg})g = (4.0\text{ kg})g + (0.5\text{ kg})g + \rho_{\text{water}}V_{\text{displaced}}g$$

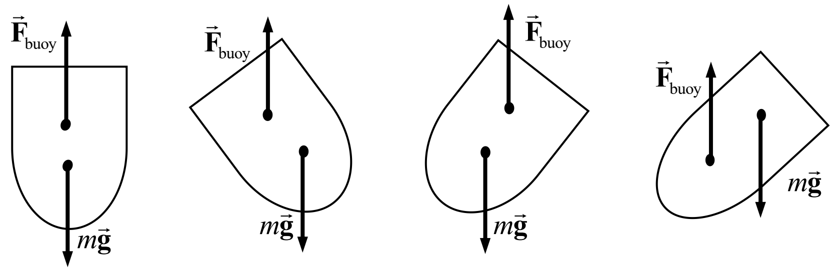
$$V_{\text{displaced}} = \frac{(5.0\text{ kg})g - (4.0\text{ kg})g - (0.5\text{ kg})g}{\rho_{\text{water}}g} = \frac{0.5\text{ kg}}{1000\text{ kg/m}^3} = 5\times 10^{-4}\text{ m}^3\left(\frac{10^6\text{ cm}^3}{1\text{ m}^3}\right)$$

$$= 500\text{ cm}^3$$

The block has a volume $V = (10\text{ cm})^3 = 1000\text{ cm}^3$, so half of the cube will be submerged. The density of the cube does not affect the solution. Therefore, the aluminum and lead cube would be submerged by the same amount.

2. (*a*) The buoyant force on the object is equal to the weight of the fluid displaced. The force of gravity of the fluid can be considered to act at the center of gravity of the fluid (see Section 7–8). If the object were removed from the fluid and that space re-filled with an equal volume of fluid, then that fluid would be in equilibrium. Since there are only two forces on that volume of fluid, gravity and the buoyant force, they must be equal in magnitude and act at the same point. Otherwise, they would be a "couple" (see Fig. 9–5), exert a nonzero torque, and cause rotation of the fluid. Since the fluid does not rotate, we may conclude that the buoyant force acts at the center of gravity.

(*b*) From the diagrams below, if the center of buoyancy (the point where the buoyancy force acts) is above the center of gravity (the point where gravity acts) of the entire ship, then when the ship tilts, the net torque about the center of mass will tend to reduce the tilt. If the center of buoyancy is below the center of gravity of the entire ship, then when the ship tilts, the net torque about the center of mass will tend to increase the tilt. Stability is achieved when the center of buoyancy is above the center of gravity.



3. (*a*) Let object 1 be the object with the greater volume, so $V_1 > V_2$. The apparent weight of each object is the difference between its actual weight and the buoyant force. Since both objects are fully submerged, the buoyant force is equal to the product of the density of the water, their volumes, and the acceleration of gravity. We set the apparent weights equal and solve for the actual weight of object 1. We use the symbol W for the actual weight.

$$W_1 - \rho_{water}V_1 g = W_2 - \rho_{water}V_2 g \quad \rightarrow \quad W_1 = W_2 + \rho_{water}(V_1 - V_2)g$$

The larger object has the greater weight.

(*b*) Since $V_1 > V_2$ and their apparent weights are equal, the ratio of the apparent weight of object 1 to its volume will be less than the ratio of the apparent weight of object 2 to its volume.

$$\frac{W_1 - \rho_{water}V_1 g}{V_1} < \frac{W_2 - \rho_{water}V_2 g}{V_2} \rightarrow \frac{m_1 g}{V_1} - \rho_{water} g < \frac{m_2 g}{V_2} - \rho_{water} g \rightarrow$$

$$\rho_1 - \rho_{water} < \rho_2 - \rho_{water} \rightarrow \boxed{\rho_1 < \rho_2}$$

The smaller object has the greater density.

4.

Assumptions in Bernoulli's equation	Modifications if assumptions were not made
Steady flow	If the flow rate can vary with time, then each of the terms in Bernoulli's equation could also vary with time. Additional terms would be needed to account for the energy needed to change the flow rates.
Laminar flow	Without laminar flow, turbulence and eddy currents could exist. These would create energy losses due to heating that would need to be accounted for in the equation.
Incompressible fluid	Work is done on the fluid as it compresses, and the fluid does work as it expands. This energy would need to be accounted for in the equation.
Nonviscous fluid	Greater pressure differences would be needed to overcome energy lost to viscous forces. Pressure and velocity would also depend upon distance from pipe walls.

5. From Section 9–5, Eq. 9–7 gives the change in volume due to pressure change as $\frac{\Delta V}{V_0} = -\frac{\Delta P}{B}$, 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 Δh 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, so $\Delta P \approx \rho_0 g \Delta h$. 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, ρ.

$$\rho V = \rho_0 V_0 \quad \rightarrow \quad \rho = \frac{\rho_0 V_0}{V} = \frac{\rho_0 V_0}{V_0 + \Delta V} = \frac{\rho_0 V_0}{V_0 + \left(-V_0 \dfrac{\Delta P}{B}\right)} = \frac{\rho_0}{1 - \dfrac{\rho_0 g h}{B}}$$

$$\rho = \frac{1025\ \text{kg/m}^3}{1 - \dfrac{(1025\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(5.4\times 10^3\ \text{m})}{2.0\times 10^9\ \text{N/m}^2}} = 1054\ \text{kg/m}^3 \approx \boxed{1.05\times 10^3\ \text{kg/m}^3}$$

$$\frac{\rho}{\rho_0} = \frac{1054}{1025} = 1.028$$

The density at the 5.4-km depth is about $\boxed{\text{3\% larger}}$ than the density at the surface.