

Chapter 15

Fluids

Answers to Even-numbered Conceptual Questions

2. No, because the Moon has no atmosphere to press down on the surface of the liquid.
4. A suction cup is held in place by atmospheric pressure. When the cup is applied, you push it flat against the surface you want to stick it to. This expels most of the air in the cup, and leads to a larger pressure on the outside of the cup. Thus, atmospheric pressure pushes the outside of the cup against the surface.
6. The balloon moves toward the front of the car. The reason is that as the car accelerates forward, the air inside it shifts toward the rear of the car – just as passengers are pressed back into their seats. This makes the pressure of the air in the car increase as one moves from front to back. The helium-filled balloon moves in the direction of decreasing pressure – like any buoyant object – which in this case is toward the front of the car.
8. Mercury is more practical in a barometer than water because of its greater density. With such a large density, the height of the mercury column is only about 0.760 m. The density of water is less than that of mercury by roughly a factor of 14. Therefore, the height of a water column in a barometer would be about 10 m – the height of a three-story building.
10. In a hot-air balloon, vertical motion is controlled by adding heat to the air in the balloon, or by letting it cool off. As the temperature of the air in the balloon changes, so too does its density. By controlling the overall density of the balloon, one can control whether it rises, falls, or is neutrally buoyant.
12. Whether the block is upright or inverted, its weight is the same. Therefore, the volume of water that must be displaced to float the block is the same in either orientation. As a result, the water level in the tank remains the same.
14. The total mass contained in the flask is the same before and after the string breaks. It follows that the reading on the scale will be the same.
16. The physics in this case is pretty “ugly”. Ice floats in water, whether it is a house-sized iceberg, a car-sized chunk, or a thimble-sized ice cube. If the Earth is warming and icebergs are breaking up into smaller pieces, each of the smaller pieces will be just as buoyant as the original berg.
18. (a) The boat is now carrying a reduced weight. Therefore, it floats higher relative to the water. (b) The water level in the pool remains the same because the blocks of wood displace the same amount of water whether they are in the boat or in the water. In either case, they displace a volume of water with a weight equal to their weight.
20. The problem is that as you go deeper into the water, the pressure pushing against your chest and lungs increases rapidly. Even if you had a long tube on your snorkel, you would find it difficult to expand your lungs to take a breath. The air coming through the snorkel would be at atmospheric pressure, but the water pushing against your chest might have twice that pressure. Thus, scuba gear not only holds air for you in a tank, but feeds it to you under pressure.

22. The fish is neutrally buoyant as it holds the pebble; therefore, it displaces a volume of water equal to its weight plus the weight of the pebble. When the fish drops the pebble it readjusts its swim bladder to be neutrally buoyant again. In this case, the fish displaces water equal to its weight, but the pebble displaces a volume of water equal only to its own volume. This is a smaller volume of water than was displaced before the pebble was dropped, and hence the water level falls.
24. A metal boat can float if it displaces a volume of water whose weight is equal to the weight of the boat. This can be accomplished by giving the boat a bowl-like shape, as illustrated in Figure 15-10.
26. The marble will stay where it is released. The reason is that the surface of the water is perpendicular to the local “effective” gravity of the rotating turntable. Even the water itself does not flow inward or outward when it is tilted at this angle. If the water is frozen, and a marble is placed on its surface, the marble will stay put just as the liquid water did before it was frozen.
28. As wind blows across the top of the chimney, a pressure difference is established between the top and bottom of the chimney, with the top having the lower pressure. This will cause smoke to rise more rapidly.
30. If a ball is placed in the stream of air such that the speed of air over its upper surface is greater than the speed across its lower surface, the result will be a lower pressure at the top of the ball. This results in an upward force that can equal the weight of the ball.
32. Assuming the leg is below heart level, as in a standing person, the blood pressure will be greater. This is simply a reflection of the fact that the pressure in a fluid increases with depth. For more details, see Figure 15-15 and Exercise 15-4.

Solutions to Problems

1. The volume of air in a typical classroom is on the order of 10^2 m^3 .

$$W = mg = \rho Vg = \left(1.29 \frac{\text{kg}}{\text{m}^3}\right)(10^2 \text{ m}^3)\left(9.81 \frac{\text{m}}{\text{s}^2}\right) = \boxed{10^3 \text{ N}}$$

2. $W = mg = \rho Vg = \left(1000 \frac{\text{kg}}{\text{m}^3}\right)(25 \text{ gal})\left(\frac{3.79 \times 10^{-3} \text{ m}^3}{\text{gal}}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right) = \boxed{0.93 \text{ kN}}$

3. $\rho = \frac{m}{V} = \frac{0.016 \text{ g}}{0.0020 \text{ cm}^3} = 8.0 \text{ g/cm}^3$
 $\rho_{\text{gold}} = 19.3 \text{ g/cm}^3$

The ring is not solid gold.

4. $V = 10^{-1} \text{ m}^3$, $\rho_{\text{gold}} = 19.3 \frac{\text{g}}{\text{cm}^3} = 1.93 \times 10^4 \frac{\text{kg}}{\text{m}^3}$

$$W = mg = \rho Vg = \left(1.93 \times 10^4 \frac{\text{kg}}{\text{m}^3}\right)(10^{-1} \text{ m}^3)\left(9.81 \frac{\text{m}}{\text{s}^2}\right) = \boxed{10^4 \text{ N}}$$

$$5. \quad \rho = \frac{m}{V} = \frac{0.347 \text{ kg}}{\left[(3.21 \text{ cm})\left(\frac{1 \text{ m}}{100 \text{ cm}}\right)\right]^3} = \boxed{1.05 \times 10^4 \text{ kg/m}^3; \text{ silver}}$$

$$6. \quad F = PA = \left(1.01 \times 10^5 \frac{\text{N}}{\text{m}^2}\right)(100 \text{ yd})(50 \text{ yd})\left(\frac{3 \text{ ft}}{\text{yd}}\right)^2 \left(\frac{\text{m}}{3.281 \text{ ft}}\right)^2 = \boxed{4.22 \times 10^8 \text{ N}}$$

$$7. \quad (\text{a}) \quad \left(\frac{10^{-5} \text{ N}}{\text{cm}^2}\right)\left(\frac{100 \text{ cm}}{\text{m}}\right)^2 = \boxed{10^{-1} \text{ Pa}}$$

$$(\text{b}) \quad (10^{-1} \text{ Pa})\left(\frac{1 \text{ atm}}{101.3 \times 10^3 \text{ Pa}}\right) = \boxed{10^{-6} \text{ atm}}$$

$$8. \quad P = \frac{F}{A} = \frac{mg}{A} = \frac{(67 \text{ kg} + 3.5 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)}{4\pi \left(\frac{0.015 \text{ m}}{2}\right)^2} = \boxed{9.8 \times 10^5 \text{ Pa}}$$

9. P_w = pressure with tip

P_{wo} = pressure without tip

$$\frac{P_w}{P_{wo}} = \frac{\frac{F}{A_w}}{\frac{F}{A_{wo}}} = \frac{A_{wo}}{A_w} = \frac{\pi r_{wo}^2}{\pi r_w^2} = \frac{(1.2 \text{ cm})^2}{(2.5 \text{ cm})^2} = 0.23, \text{ so pressure is reduced by a factor of } \boxed{4.3}.$$

$$10. \quad P = P_{\text{atm}} + P_g = 14.7 \frac{\text{lb}}{\text{in}^2} + 9.5 \frac{\text{lb}}{\text{in}^2} = \boxed{24.2 \text{ lb/in}^2}$$

$$11. \quad F = PA$$

$$m_T g = PA$$

$$m_T = \frac{PA}{g}$$

$$= \frac{\left(70.5 \frac{\text{lb}}{\text{in}^2}\right)\left(\frac{1.01 \times 10^5 \text{ Pa}}{14.7 \frac{\text{lb}}{\text{in}^2}}\right)(2)(7.13 \text{ cm}^2)\left(\frac{\text{m}}{100 \text{ cm}}\right)^2}{9.81 \frac{\text{m}}{\text{s}^2}}$$

$$= 70.4 \text{ kg}$$

$$= 7.70 \text{ kg} + m$$

$$m = 62.7 \text{ kg}$$

$$W = mg = (62.7 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right) = \boxed{615 \text{ N}}$$

12. (a) $\frac{F}{P} = A$

$$\frac{mg}{P} = 4A_{\text{tire}}$$

$$A_{\text{tire}} = \frac{mg}{4P}$$

$$= \frac{(1320 \text{ kg}) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)}{4 \left(35.0 \frac{\text{lb}}{\text{in}^2} \right) \left(\frac{1.01 \times 10^5 \text{ Pa}}{14.7 \frac{\text{lb}}{\text{in}^2}} \right)} = \boxed{0.0135 \text{ m}^2}$$

(b) The area of contact decreases.

(c) $P = \frac{mg}{4A_{\text{tire}}} = \frac{(1320 \text{ kg}) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)}{4(116 \text{ cm}^2) \left(\frac{1 \text{ m}}{100 \text{ cm}} \right)^2} = \left(2.79 \times 10^5 \text{ Pa} \right) \left(\frac{14.7 \frac{\text{lb}}{\text{in}^2}}{1.01 \times 10^5 \text{ Pa}} \right) = \boxed{40.6 \text{ lb/in}^2}$

13. $P = P_{\text{atm}} + \rho gh = 1.01 \times 10^5 \text{ Pa} + \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right) (221 \text{ m}) = \boxed{2.27 \times 10^6 \text{ Pa}}$

14. $(740 \text{ mmHg}) \left(\frac{1.01 \times 10^5 \text{ Pa}}{760 \text{ mmHg}} \right) = \boxed{9.8 \times 10^4 \text{ Pa}}$

15. $F = P_{\text{at}} A = P_{\text{at}} (h\pi d) = (1.01 \times 10^5 \text{ N/m}^2) (0.12 \text{ m}) (\pi) (0.065 \text{ m}) = \boxed{2.5 \text{ kN}}$

16. $P_L = P_R$

$$\frac{m_L g}{A_L} + \rho gh_L = \frac{m_R g}{A_R} + \rho gh_R$$

$$h_R - h_L = \frac{1}{\rho} \left(\frac{m_L}{A_L} - \frac{m_R}{A_R} \right) = \frac{1}{\rho} \left(\frac{m_L}{\frac{\pi D_L^2}{4}} - \frac{m_R}{\frac{\pi D_R^2}{4}} \right) = \frac{4}{\pi \rho} \left(\frac{m_L}{D_L^2} - \frac{m_R}{D_R^2} \right) = \frac{4}{\pi \left(\frac{750 \text{ kg}}{\text{m}^3} \right)} \left[\frac{1.7 \text{ kg}}{(0.045 \text{ m})^2} - \frac{3.2 \text{ kg}}{(0.12 \text{ m})^2} \right] = \boxed{1.0 \text{ m}}$$

17. At the interface of the top of the barrel and the bottom of the tube, the pressure can have only one value.

$$\begin{aligned}
 P_{\text{tube}} &= P_{\text{barrel}} \\
 \frac{W}{A_{\text{tube}}} &= \frac{F}{A_{\text{barrel}}} \\
 W &= \left(\frac{A_{\text{tube}}}{A_{\text{barrel}}} \right) F \\
 &= \left[\frac{\pi \left(\frac{d}{2} \right)^2}{\pi \left(\frac{D}{2} \right)^2} \right] F \\
 &= \left(\frac{d}{D} \right)^2 F \\
 &= \left(\frac{0.01 \text{ m}}{0.75 \text{ m}} \right)^2 (6430 \text{ N}) \\
 &= \boxed{1.1 \text{ N}}
 \end{aligned}$$

18. (a) $P = P_{\text{at}} + \rho gh$

$$\begin{aligned}
 h &= \frac{P - P_{\text{at}}}{\rho g} \\
 &= \frac{110 \times 10^3 \text{ Pa} - 1.01 \times 10^5 \text{ Pa}}{\left(806 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)} \\
 &= \boxed{1.14 \text{ m}}
 \end{aligned}$$

- (b) The additional height is $\frac{2.05 \times 10^{-3} \text{ m}^3}{65.2 \times 10^{-4} \text{ m}^2} = 0.314 \text{ m}$.

$$P = P_{\text{at}} + \rho gh = 1.01 \times 10^5 \text{ Pa} + \left(806 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right) (1.138 \text{ m} + 0.3144 \text{ m}) = \boxed{112 \text{ kPa}}$$

19. (a) $P = P_{\text{atm}} + \rho_w gh$

$$\begin{aligned}
 h &= \frac{P - P_{\text{atm}}}{\rho_w g} \\
 &= \frac{10.0 \frac{\text{N}}{(\text{mm})^2} \left(\frac{10^3 \text{ mm}}{\text{m}} \right)^2 - 1.01 \times 10^5 \text{ Pa}}{\left(1025 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)} \\
 &= \boxed{984 \text{ m}}
 \end{aligned}$$

- (b) Fresh water is less dense than sea water, so the maximum safe depth in fresh water is greater than in salt water.

20. (a) $P = P_{\text{at}} + \rho gh = 1.01 \times 10^5 \text{ Pa} + \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right) (4.0 \text{ m}) = \boxed{1.4 \times 10^5 \text{ Pa}}$

(b) $P = 1.01 \times 10^5 \text{ Pa} + \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right) (5.0 \text{ m}) = \boxed{1.5 \times 10^5 \text{ Pa}}$

(c) Because pressure increases with depth.

21. (a) The force the glass bottom exerts upward on the water is greater than the weight of the water in order to provide upward acceleration. By Newton's Third Law, the water exerts an equal force downward on the glass bottom, so the pressure is greater than it was before the elevator began to move.

(b) $a = \frac{\Delta v}{\Delta t} = \frac{2.2 \text{ m/s} - 0}{3.1 \text{ s}} = 0.710 \text{ m/s}^2$

Apply Newton's 2nd Law to the fluid.

$$\Sigma F_y = ma$$

$$N - W = ma$$

$$N = ma + W$$

$$N = ma + mg$$

$$\frac{N}{A} = \frac{m}{A}(a + g)$$

Since $m = \rho V = \rho Ah$, $\frac{m}{A} = \rho h$.

$$P_g = \frac{N}{A} = \rho h(a + g) = \left(1000 \frac{\text{kg}}{\text{m}^3}\right)(0.065 \text{ m})\left(0.710 \frac{\text{m}}{\text{s}^2} + 9.81 \frac{\text{m}}{\text{s}^2}\right) = 684 \text{ Pa}$$

$$P = P_{\text{at}} + P_g = 1.013 \times 10^5 \text{ Pa} + 684 \text{ Pa} = \boxed{1.02 \times 10^5 \text{ Pa}}$$

22. $P = P_{\text{at}} + \rho_w g h_w + \rho_{\text{oil}} g h_{\text{oil}}$

$$= 1.013 \times 10^5 \text{ Pa} + \left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(0.12 \text{ m}) + \left(0.92 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(0.072 \text{ m})$$

$$= \boxed{1.03 \times 10^5 \text{ Pa}}$$

23. $P_A = P_{\text{at}} + \rho_w g h_w + \rho_{\text{oil}} g h_{\text{oil},A}$

$$P_B = P_{\text{at}} + \rho_{\text{oil}} g h_{\text{oil},B}$$

$$P_A = P_B$$

$$P_{\text{at}} + \rho_w g h_w + \rho_{\text{oil}} g h_{\text{oil},A} = P_{\text{at}} + \rho_{\text{oil}} g h_{\text{oil},B}$$

$$\rho_w g h_w + \rho_{\text{oil}} g h_{\text{oil},A} = \rho_{\text{oil}} g h_{\text{oil},B}$$

$$h_w = \frac{\rho_{\text{oil}}(h_{\text{oil},B} - h_{\text{oil},A})}{\rho_w} = \frac{\left(920 \frac{\text{kg}}{\text{m}^3}\right)(0.0500 \text{ m} - 0.0300 \text{ m})}{1000 \frac{\text{kg}}{\text{m}^3}} \quad h_w = 0.0184 \text{ m}$$

$$\Delta h = h_{\text{oil},B} - (h_w + h_{\text{oil},A}) = 0.0500 \text{ m} - (0.0184 \text{ m} + 0.0300 \text{ m}) = (0.0016 \text{ m})\left(\frac{100 \text{ cm}}{\text{m}}\right) = \boxed{0.16 \text{ cm}}$$

24. (a) The atmospheric pressure that is exerted on the surface of the water creates an upward force on the water column in the straw that overcomes the force of gravity.

(b) $P_{\text{at}} = \rho g h$

$$h = \frac{P_{\text{at}}}{\rho g} = \frac{1.01 \times 10^5 \text{ Pa}}{\left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)} = \boxed{10.3 \text{ m}}$$

25. (a) $P = P_{\text{at}} + \rho gh$

$$h = \frac{P - P_{\text{at}}}{\rho g} = \frac{109 \text{ kPa} - 101.3 \text{ kPa}}{\left(1020 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)} = \boxed{0.770 \text{ m}}$$

(b) Increased; the gauge pressure in a fluid is proportional to its density.

26. $P = P_{\text{at}} + \rho_w gh_w + \rho_{\text{Hg}} gh_{\text{Hg}}$

$$2P_{\text{at}} = P_{\text{at}} + \rho_w g(1.0 \text{ m} - d) + \rho_{\text{Hg}} gd$$

$$P_{\text{at}} = g[\rho_w (1.0 \text{ m}) + d(\rho_{\text{Hg}} - \rho_w)]$$

$$d = \frac{\frac{P_{\text{at}}}{g} - \rho_w (1.0 \text{ m})}{\rho_{\text{Hg}} - \rho_w} = \frac{\frac{1.01 \times 10^5 \text{ Pa}}{9.81 \frac{\text{m}}{\text{s}^2}} - \left(1000 \frac{\text{kg}}{\text{m}^3}\right)(1.0 \text{ m})}{1.36 \times 10^4 \frac{\text{kg}}{\text{m}^3} - 1000 \frac{\text{kg}}{\text{m}^3}} = \boxed{0.74 \text{ m}}$$

27. $\Delta F_b = W = \rho Vg = \left(1000 \frac{\text{kg}}{\text{m}^3}\right)(4.2 \text{ m})(6.5 \text{ m})(0.027 \text{ m})\left(9.81 \frac{\text{m}}{\text{s}^2}\right) = \boxed{7.2 \text{ kN}}$

28. $F_B = \rho Vg$

$$\frac{mg}{2} = \rho(lwh)g$$

$$l = \frac{m}{2\rho wh}$$

$$= \frac{75 \text{ kg}}{2\left(1000 \frac{\text{kg}}{\text{m}^3}\right)(0.35 \text{ m})(0.25 \text{ m})}$$

$$= (0.429 \text{ m})\left(\frac{100 \text{ cm}}{\text{m}}\right)$$

$$= \boxed{43 \text{ cm}}$$

29. $F_b = \rho_{\text{air}} Vg = \rho_{\text{air}} \left[\frac{4}{3}\pi r^3\right]g = \left(1.16 \frac{\text{kg}}{\text{m}^3}\right)\left[\frac{4}{3}\pi(5.2 \text{ m})^3\right]\left(9.81 \frac{\text{m}}{\text{s}^2}\right) = 6702 \text{ N}$

Ignoring the mass of the helium,

$$\text{lifting force} = F_b - m_{\text{balloon}}g - \rho_{\text{He}}V_{\text{He}}g$$

$$= 6702 \text{ N} - (0.12 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right) - \left(0.179 \frac{\text{kg}}{\text{m}^3}\right)\left[\frac{4}{3}\pi(5.2 \text{ m})^3\right]\left(9.81 \frac{\text{m}}{\text{s}^2}\right)$$

$$= \boxed{5.7 \text{ kN}}$$

30. $m = \text{mass of hot air}$

$$M = \text{mass of balloon} + \text{cargo}$$

$$F_b = Mg + mg$$

$$\rho_{\text{air}} Vg = Mg + \rho_{\text{hot air}} Vg$$

$$\rho_{\text{hot air}} = \rho_{\text{air}} - \frac{M}{V} = 1.29 \frac{\text{kg}}{\text{m}^3} - \frac{327 \text{ kg}}{687 \text{ m}^3} = \boxed{0.814 \text{ kg/m}^3}$$

31. $\Delta W_{\text{Total}} = W_{\text{metal}} - F_{\text{string}} = \rho_{\text{metal}} V_{\text{metal}} g - (\rho_{\text{metal}} V_{\text{metal}} g - \rho_w V_{\text{metal}} g) = \boxed{\rho_w V_{\text{metal}} g}$

$$\begin{aligned}
 32. \quad m_{\max} &= \frac{W_{\max}}{g} \\
 &= \frac{F_b - mg}{g} \\
 &= \frac{\rho V g - mg}{g} \\
 &= \rho l w h - m \\
 &= \left(1000 \frac{\text{kg}}{\text{m}^3}\right)(2.2 \text{ m})(0.65 \text{ m})(0.13 \text{ m}) - 0.22 \text{ kg} \\
 &= \boxed{190 \text{ kg}}
 \end{aligned}$$

33. (a) W_s = weight of block submerged in water

W = weight of block in air

$$W_s = W - F_b$$

$$W_s = W - \rho_w V g$$

$$V = \frac{W - W_s}{\rho_w g}$$

$$\begin{aligned}
 &= \frac{20.0 \text{ N} - 17.7 \text{ N}}{\left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)} \\
 &= \boxed{2.34 \times 10^{-4} \text{ m}^3}
 \end{aligned}$$

$$(b) \quad \rho = \frac{m}{V} = \frac{W}{gV} = \frac{20.0 \text{ N}}{\left(9.81 \frac{\text{m}}{\text{s}^2}\right)\left(2.345 \times 10^{-4} \text{ m}^3\right)} = \boxed{8.70 \times 10^3 \text{ kg/m}^3}$$

34. (a) W_w = weight of block in water

W_a = weight of block in alcohol

W = weight of block in air

$$W_w = W - F_{b,w} \quad W_a = W - F_{b,a}$$

$$W = W_w + F_{b,w} \quad W = W_a + F_{b,a}$$

$$W = W_w + \rho_w V g \quad W = W_a + \rho_a V g$$

$$W_w + \rho_w V g = W_a + \rho_a V g$$

$$W_w - W_a = \rho_a V g - \rho_w V g$$

$$\begin{aligned}
 V &= \frac{W_w - W_a}{(\rho_a - \rho_w)g} \\
 &= \frac{25.0 \text{ N} - 25.7 \text{ N}}{\left(806 \frac{\text{kg}}{\text{m}^3} - 1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)} \\
 &= \boxed{3.68 \times 10^{-4} \text{ m}^3}
 \end{aligned}$$

$$\begin{aligned}
 \text{(b)} \quad \rho_{\text{block}} &= \frac{m_{\text{block}}}{V} \\
 &= \frac{\frac{W_{\text{block}}}{g}}{V} \\
 &= \frac{\frac{W_{\text{w}} + \rho_{\text{w}} V g}{g}}{V} \\
 &= \frac{W_{\text{w}}}{gV} + \rho_{\text{w}} \\
 &= \frac{25.0 \text{ N}}{\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(3.68 \times 10^{-4} \text{ m}^3)} + 1000 \frac{\text{kg}}{\text{m}^3} \\
 &= \boxed{7.93 \times 10^3 \text{ kg/m}^3}
 \end{aligned}$$

35. (a) Use Siri's formula.

$$\begin{aligned}
 x_{\text{f}} &= \frac{4950 \frac{\text{kg}}{\text{m}^3}}{\rho_{\text{p}}} - 4.50 \\
 \rho_{\text{p}} &= \frac{4950 \frac{\text{kg}}{\text{m}^3}}{x_{\text{f}} + 4.50} \\
 &= \frac{4950 \frac{\text{kg}}{\text{m}^3}}{0.184 + 4.50} \\
 &= \boxed{1060 \text{ kg/m}^3}
 \end{aligned}$$

$$\text{(b)} \quad V_{\text{p}} = \frac{m}{\rho_{\text{p}}} = \frac{1}{\rho_{\text{p}}} \left(\frac{W}{g} \right) = \frac{768 \text{ N}}{\left(1057 \frac{\text{kg}}{\text{m}^3}\right) \left(9.81 \frac{\text{m}}{\text{s}^2}\right)} = \boxed{0.0741 \text{ m}^3}$$

$$\text{(c)} \quad W_{\text{a}} = W - F_{\text{b}} = W - \rho_{\text{w}} V_{\text{p}} g = 768 \text{ N} - \left(1000 \frac{\text{kg}}{\text{m}^3}\right) (0.0741 \text{ m}^3) \left(9.81 \frac{\text{m}}{\text{s}^2}\right) = \boxed{41 \text{ N}}$$

$$\begin{aligned}
 \text{36. (a)} \quad F_{\text{b}} &= W \\
 \rho_{\text{w}} V_{\text{submerged}} g &= \rho_{\text{log}} V g \\
 \rho_{\text{log}} &= \rho_{\text{w}} \left(\frac{V_{\text{submerged}}}{V} \right) \\
 &= \left(1000 \frac{\text{kg}}{\text{m}^3}\right) \left(\frac{3}{4}\right) \\
 &= \boxed{750 \text{ kg/m}^3}
 \end{aligned}$$

(b) It increases because the buoyant force is proportional to the density of the displaced fluid and the density of salt water is greater than the density of fresh water.

37. (a) $F_b = W$
 $\rho_w V_{\text{submerged}} g = mg$
 $V_{\text{submerged}} = \frac{m}{\rho_w}$
 $V_{\text{above water}} = V_{\text{total}} - V_{\text{submerged}} = V_{\text{total}} - \frac{m}{\rho_w} = 0.089 \text{ m}^3 - \frac{81 \text{ kg}}{1000 \frac{\text{kg}}{\text{m}^3}} = \boxed{0.0080 \text{ m}^3}$

(b) $F_{\text{applied}} + F_b = W$
 $F_{\text{applied}} = W - F_b$
 $= mg - \rho_w V_{\text{submerged}} g$
 $= mg - \rho_w (V_{\text{total}} - V_{\text{above water}} - 0.0018 \text{ m}^3) g$
 $= (81 \text{ kg}) \left(9.81 \frac{\text{m}}{\text{s}^2} \right) - \left(1000 \frac{\text{kg}}{\text{m}^3} \right) (0.089 \text{ m}^3 - 0.0080 \text{ m}^3 - 0.0018 \text{ m}^3) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)$
 $= \boxed{18 \text{ N}}$

38. (a) The block is submerged in less water than before because the oil provides additional buoyant force.

(b) Before oil is added:

$$\begin{aligned} F_b &= \rho_w V_{\text{submerged}} g \\ &= \rho_w (0.9 V_{\text{total}}) g \\ &= 0.9 \rho_w V_{\text{total}} g \end{aligned}$$

After oil is added:

$$\begin{aligned} F_{b,w} + F_{b,oil} &= F_b \\ \rho_w V_{\text{in water}} g + \rho_{\text{oil}} V_{\text{in oil}} g &= 0.9 \rho_w V_{\text{total}} g \end{aligned}$$

Let f_w = fraction of block in water

f_{oil} = fraction of block in oil

Substitute.

$$\begin{aligned} \rho_w f_w V_{\text{total}} + \rho_{\text{oil}} f_{\text{oil}} V_{\text{total}} &= 0.9 \rho_w V_{\text{total}} \\ \rho_w f_w + \rho_{\text{oil}} (1 - f_w) &= 0.9 \rho_w \\ f_w (\rho_w - \rho_{\text{oil}}) &= 0.9 \rho_w - \rho_{\text{oil}} \\ f_w &= \frac{0.9 \rho_w - \rho_{\text{oil}}}{\rho_w - \rho_{\text{oil}}} \\ &= \frac{0.9 \left(1000 \frac{\text{kg}}{\text{m}^3} \right) - 875 \frac{\text{kg}}{\text{m}^3}}{1000 \frac{\text{kg}}{\text{m}^3} - 875 \frac{\text{kg}}{\text{m}^3}} \\ &= \boxed{0.2} \end{aligned}$$

39.

$$\begin{aligned}
 F_b &= W \\
 \rho_{\text{Hg}} V_{\text{submerged}} g &= mg \\
 \rho_{\text{Hg}} V_{\text{submerged}} &= \rho_{\text{lead}} V \\
 \rho_{\text{Hg}} \left(\frac{\pi D^2 h_{\text{submerged}}}{4} \right) &= \rho_{\text{lead}} \left(\frac{\pi D^2 h}{4} \right) \\
 h_{\text{submerged}} &= \frac{\rho_{\text{lead}}}{\rho_{\text{Hg}}} h \\
 &= \frac{11.3 \times 10^3 \frac{\text{kg}}{\text{m}^3}}{13.6 \times 10^3 \frac{\text{kg}}{\text{m}^3}} (0.025 \text{ m}) \\
 &= \boxed{2.1 \text{ cm}}
 \end{aligned}$$

40. (a)

$$\begin{aligned}
 \Sigma F_y &= ma_y \\
 T + F_b - mg &= ma \\
 T &= mg + ma - F_b \\
 &= m(g + a) - \rho_w V g \\
 &= \rho_{\text{lead}} V (g + a) - \rho_w V g \\
 &= V [\rho_{\text{lead}} (g + a) - \rho_w g] \\
 &= (0.82 \times 10^{-5} \text{ m}^3) \left[\left(11.3 \times 10^3 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} + 2.1 \frac{\text{m}}{\text{s}^2} \right) - \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right) \right] \\
 &= \boxed{1.0 \text{ N}}
 \end{aligned}$$

(b) The tension stays the same because the only quantity that changes with depth is pressure. The buoyant force and thus, the tension don't depend on pressure.

(c)

$$\begin{aligned}
 \Sigma F_y &= ma_y \\
 T + F_b - mg &= ma \\
 \frac{T + \rho_w V g - \rho_{\text{lead}} V g}{m} &= a \\
 a &= \frac{T + (\rho_w - \rho_{\text{lead}}) V g}{\rho_{\text{lead}} V} \\
 &= \frac{1.2 \text{ N} + \left(1000 \frac{\text{kg}}{\text{m}^3} - 11.3 \times 10^3 \frac{\text{kg}}{\text{m}^3} \right) (0.82 \times 10^{-5} \text{ m}^3) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)}{\left(11.3 \times 10^3 \frac{\text{kg}}{\text{m}^3} \right) (0.82 \times 10^{-5} \text{ m}^3)} \\
 &= \boxed{4.0 \frac{\text{m}}{\text{s}^2}}
 \end{aligned}$$

$$\vec{a} = 4.0 \text{ m/s}^2 \text{ upward}$$

41. $A_1 v_1 = A_2 v_2$

$$\left(\frac{\pi D_1^2}{4} \right) v_1 = \left(\frac{\pi D_2^2}{4} \right) v_2$$

$$v_2 = \left(\frac{D_1}{D_2} \right)^2 v_1$$

$$= \left(\frac{3.2 \text{ cm}}{0.55 \text{ cm}} \right)^2 \left(1.3 \frac{\text{m}}{\text{s}} \right)$$

$$= \boxed{44 \text{ m/s}}$$

42. $\frac{\Delta m}{\Delta t} = \rho A v = \rho \left(\frac{\pi D^2}{4} \right) v = \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left[\frac{\pi (0.038 \text{ m})^2}{4} \right] \left(2.1 \frac{\text{m}}{\text{s}} \right) = \boxed{2.4 \text{ kg/s}}$

43. $\Delta t = \frac{\Delta m}{\rho A v}$

$$= \frac{\rho V}{\rho A v}$$

$$= \frac{\frac{\pi D_{\text{pool}}^2 h}{4}}{\frac{\pi D_{\text{hose}}^2 v}{4}}$$

$$= \frac{h \left(\frac{D_{\text{pool}}}{D_{\text{hose}}} \right)^2}{v}$$

$$= \frac{0.26 \text{ m} \left(\frac{2.0 \text{ m}}{0.028 \text{ m}} \right)^2}{1.1 \frac{\text{m}}{\text{s}}}$$

$$= \boxed{1.2 \times 10^3 \text{ s}}$$

44. $\Delta V = \left(\frac{\Delta V}{\Delta t} \right) t = \left(5.00 \frac{\text{L}}{\text{min}} \right) \left(\frac{60 \text{ min}}{\text{h}} \right) \left(\frac{24 \text{ h}}{\text{day}} \right) = \boxed{7200 \text{ L}}$

$$m = \rho \Delta V = \left(1060 \frac{\text{kg}}{\text{m}^3} \right) (7200 \text{ L}) \left(\frac{\text{m}^3}{10^3 \text{ L}} \right) = \boxed{7630 \text{ kg}}$$

45. (a) $\frac{\Delta V}{\Delta t} = A v$

$$v = \frac{\frac{\Delta V}{\Delta t}}{A} = \frac{5.5 \times 10^{-6} \text{ cm}^3/\text{s}}{\pi \left(\frac{0.0030 \text{ cm}}{2} \right)^2}$$

$$= \boxed{0.78 \text{ cm/s}}$$

(b) $v = \frac{\left(\frac{5.5 \times 10^{-6} \text{ cm}^3/\text{s}}{340} \right)}{\pi \left(\frac{4.0 \times 10^{-4} \text{ cm}}{2} \right)^2} = \boxed{0.13 \text{ cm/s}}$

$$\begin{aligned}
 46. \quad (a) \quad \frac{\Delta m}{\Delta t} &= \rho A v \\
 v &= \frac{\Delta m}{\Delta t} \frac{1}{\rho A} \\
 &= \frac{\Delta m}{\Delta t} \frac{4}{\rho \pi D^2} \\
 &= \left(3.11 \frac{\text{kg}}{\text{s}} \right) \frac{4}{\left(1000 \frac{\text{kg}}{\text{m}^3} \right) \pi (0.0310 \text{ m})^2} \\
 &= \boxed{4.12 \text{ m/s}}
 \end{aligned}$$

$$\begin{aligned}
 (b) \quad A_1 v_1 &= A_2 v_2 \\
 \frac{\pi D_1^2}{4} v_1 &= \frac{\pi D_2^2}{4} v_2 \\
 v_2 &= \left(\frac{D_1}{D_2} \right)^2 v_1 \\
 &= \left(\frac{3.10 \text{ cm}}{0.750 \text{ cm}} \right)^2 \left(4.12 \frac{\text{m}}{\text{s}} \right) \\
 &= \boxed{70.4 \text{ m/s}}
 \end{aligned}$$

(c) Equal, because for incompressible fluids, conservation of mass requires that “goes into equals comes out of.”

$$\begin{aligned}
 47. \quad A_1 v_1 &= A_2 v_2 \\
 w_1 d_1 v_1 &= w_2 d_2 v_2 \\
 v_2 &= \frac{w_1 d_1 v_1}{w_2 d_2} \\
 &= \frac{(12 \text{ m})(2.7 \text{ m}) \left(2.2 \frac{\text{m}}{\text{s}} \right)}{(4.0 \text{ m})(0.85 \text{ m})} \\
 &= \boxed{21 \text{ m/s}}
 \end{aligned}$$

$$\begin{aligned}
 48. \quad A_a v_a &= n A_c v_c \\
 n &= \frac{A_a v_a}{A_c v_c} \\
 &= \frac{\frac{\pi D_a^2}{4} v_a}{\frac{\pi D_c^2}{4} v_c} \\
 &= \left(\frac{D_a}{D_c} \right)^2 \frac{v_a}{v_c} \\
 &= \left(\frac{0.0050 \text{ m}}{1.0 \times 10^{-5} \text{ m}} \right)^2 \left(\frac{1.0 \frac{\text{m}}{\text{s}}}{0.01 \frac{\text{m}}{\text{s}}} \right) \\
 &= \boxed{2.5 \times 10^7}
 \end{aligned}$$

$$\begin{aligned}
 \text{49. (a)} \quad A_1 v_1 &= A_2 v_2 \\
 v_2 &= \frac{A_1}{A_2} v_1 \\
 &= \frac{\frac{\pi D_1^2}{4}}{\frac{\pi D_2^2}{4}} v_1 \\
 &= \left(\frac{D_1}{D_2} \right)^2 v_1 \\
 &= \left(\frac{1.1 \text{ cm}}{0.75 \text{ cm}} \right)^2 \left(15 \frac{\text{cm}}{\text{s}} \right) \\
 &= \boxed{32 \text{ cm/s}}
 \end{aligned}$$

$$\begin{aligned}
 \text{(b)} \quad P_1 + \frac{1}{2} \rho v_1^2 &= P_2 + \frac{1}{2} \rho v_2^2 \\
 \Delta P &= P_1 - P_2 \\
 &= \frac{1}{2} \rho (v_2^2 - v_1^2) \\
 &= \frac{1}{2} \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left[\left(0.32 \frac{\text{m}}{\text{s}} \right)^2 - \left(0.15 \frac{\text{m}}{\text{s}} \right)^2 \right] \\
 &= \boxed{40 \text{ Pa}}
 \end{aligned}$$

$$\begin{aligned}
 \text{50. (a)} \quad A_1 v_1 &= A_2 v_2 \\
 \frac{\pi D_1^2}{4} v_1 &= \frac{\pi D_2^2}{4} v_2 \\
 v_2 &= \left(\frac{D_1}{D_2} \right)^2 v_1 \\
 &= \left(\frac{\frac{D_1}{2}}{\frac{D_1}{2}} \right)^2 v_1 \\
 &= 4 v_1 \\
 &= 4 \left(1.4 \frac{\text{m}}{\text{s}} \right) \\
 &= \boxed{5.6 \text{ m/s}}
 \end{aligned}$$

$$\begin{aligned}
 \text{(b)} \quad P_1 + \frac{1}{2}\rho v_1^2 &= P_2 + \frac{1}{2}\rho v_2^2 \\
 P_2 &= P_1 + \frac{1}{2}\rho(v_1^2 - v_2^2) \\
 &= P_1 + \frac{1}{2}\rho[v_1^2 - (4v_1)^2] \\
 &= P_1 + \frac{1}{2}\rho(-15v_1^2) \\
 &= P_1 - \frac{15}{2}\rho v_1^2 \\
 &= 110 \times 10^3 \text{ Pa} - \frac{15}{2} \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(1.4 \frac{\text{m}}{\text{s}} \right)^2 \\
 &= \boxed{95 \text{ kPa}}
 \end{aligned}$$

$$\begin{aligned}
 51. \text{ (a)} \quad \frac{\Delta V}{\Delta t} &= Av \\
 v &= \frac{\frac{\Delta V}{\Delta t}}{A} \\
 &= \frac{\frac{\Delta V}{\Delta t}}{\left(\frac{\pi D^2}{4} \right)} \\
 &= \frac{\left(1.5 \frac{\text{L}}{\text{s}} \right) \left(\frac{1 \text{ m}^3}{1000 \text{ L}} \right)}{\frac{\pi (0.0060 \text{ m})^2}{4}} \\
 &= \boxed{53 \text{ m/s}}
 \end{aligned}$$

- (b) Take point 1 at the top of the vertical straw and point 2 out in the room. Neglect changes in room air pressure due to height.

$$\begin{aligned}
 P_1 + \frac{1}{2}\rho v_1^2 &= P_2 + \frac{1}{2}\rho v_2^2 \\
 P_2 - P_1 &= \frac{1}{2}\rho v_1^2 \quad (v_2 = 0) \\
 \Delta P &= \frac{1}{2} \left(1.16 \frac{\text{kg}}{\text{m}^3} \right) \left(53.1 \frac{\text{m}}{\text{s}} \right)^2 \\
 &= 30.8 \text{ Pa} \\
 \Delta P &= \rho_w Ahg \\
 h &= \frac{\Delta P}{\rho_w g} \\
 &= \frac{30.8 \text{ Pa}}{\left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)} \\
 &= \boxed{0.31 \text{ cm}}
 \end{aligned}$$

52. (a) The tube with the greater diameter has the higher pressure.
- (b) The tube with the smaller diameter has the higher speed of flow.

$$\begin{aligned}
 \text{(c)} \quad P_1 + \frac{1}{2}\rho v_1^2 &= P_2 + \frac{1}{2}\rho v_2^2 \\
 P_1 + \frac{1}{2}\rho v_1^2 &= P_2 + \frac{1}{2}\rho \left[\left(\frac{A_1}{A_2} \right) v_1 \right]^2 \\
 P_1 + \frac{1}{2}\rho v_1^2 &= P_2 + \frac{1}{2}\rho \left[\left(\frac{D_1}{D_2} \right)^2 v_1 \right]^2 \\
 v_1 &= \sqrt{\frac{\frac{2}{\rho}(P_2 - P_1)}{1 - \left(\frac{D_1}{D_2} \right)^4}} \\
 &= \sqrt{\frac{\frac{2}{1000 \frac{\text{kg}}{\text{m}^3}}(-7.5 \times 10^3 \text{ Pa})}{1 - \left(\frac{2.8 \text{ cm}}{1.6 \text{ cm}} \right)^4}} \\
 &= \boxed{1.3 \text{ m/s}}
 \end{aligned}$$

$$\begin{aligned}
 53. \quad P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 &= P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \\
 P_1 + 0 + 0 &= P_{\text{at}} + 0 + \rho g h_2 \\
 P_g = P_1 - P_{\text{at}} &= \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right) (0.75 \text{ m}) = \boxed{7.4 \text{ kPa}}
 \end{aligned}$$

54. Use Torricelli's Law.

$$v = \sqrt{2gh} = \sqrt{2 \left(9.81 \frac{\text{m}}{\text{s}^2} \right) (2.5 \text{ m})} = \boxed{7.0 \text{ m/s}}$$

55. (a) Apply Bernoulli's Law between a point on the upper surface and a point on the lower surface. We can neglect the difference in height between the two surfaces since the difference in static pressures between these points is negligible.

$$\begin{aligned}
 P_u + \frac{1}{2}\rho v_u^2 &= P_l + \frac{1}{2}\rho v_l^2 \\
 \Delta P &= P_l - P_u \\
 &= \frac{1}{2}\rho(v_u^2 - v_l^2) \\
 &= \frac{1}{2} \left(1.29 \frac{\text{kg}}{\text{m}^3} \right) \left[\left(115 \frac{\text{m}}{\text{s}} \right)^2 - \left(105 \frac{\text{m}}{\text{s}} \right)^2 \right] \\
 &= \boxed{1.42 \text{ kPa}}
 \end{aligned}$$

$$\text{(b)} \quad \Delta F = \Delta P A = (1.42 \times 10^3 \text{ Pa})(32 \text{ m}^2) = \boxed{45 \text{ kN}}$$

$$\begin{aligned}
 56. \quad (a) \quad P_{\text{in}} + \frac{1}{2} \rho v_{\text{in}}^2 &= P_{\text{out}} + \frac{1}{2} \rho v_{\text{out}}^2 \\
 \Delta P &= P_{\text{in}} - P_{\text{out}} \\
 &= \frac{1}{2} \rho (v_{\text{out}}^2 - v_{\text{in}}^2) \\
 &= \frac{1}{2} \left(1.29 \frac{\text{kg}}{\text{m}^3} \right) \left[\left(150 \frac{\text{m}}{\text{s}} \right)^2 - 0^2 \right] \\
 &= \boxed{15 \text{ kPa}}
 \end{aligned}$$

$$(b) \quad \Delta F = \Delta P A = (14.5 \times 10^3 \text{ Pa}) (0.25 \text{ m}) (0.42 \text{ m}) = \boxed{1.52 \text{ kN}}$$

57. (a) From Exercise 15-5,

$$\begin{aligned}
 \Delta P &= \frac{1}{2} \rho v^2 \\
 \Delta P &= \frac{1}{2} \left(1.29 \frac{\text{kg}}{\text{m}^3} \right) \left(47.7 \frac{\text{m}}{\text{s}} \right)^2 = 1.4676 \text{ kPa} \\
 \Delta F &= \Delta P A = (1.4676 \times 10^3 \text{ Pa}) (668 \text{ m}^2) = \boxed{980 \text{ kN}}
 \end{aligned}$$

(b) The force is directed upward. Stationary air exerts a larger pressure than air moving rapidly past the outside of the roof.

$$\begin{aligned}
 58. \quad (a) \quad A_1 v_1 &= A_2 v_2 \\
 v_2 &= \frac{A_1}{A_2} v_1 \\
 &= \left(\frac{D_1}{D_2} \right)^2 v_1 \\
 &= \left(\frac{0.65 \text{ in.}}{0.25 \text{ in.}} \right)^2 \left(0.55 \frac{\text{m}}{\text{s}} \right) \\
 &= \boxed{3.7 \text{ m/s}}
 \end{aligned}$$

$$\begin{aligned}
 (b) \quad P_1 + \frac{1}{2} \rho v_1^2 &= P_2 + \frac{1}{2} \rho v_2^2 \\
 P_2 &= P_1 + \frac{1}{2} \rho (v_1^2 - v_2^2) \\
 &= 1.2 (1.01 \times 10^5 \text{ Pa}) + \frac{1}{2} \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left[\left(0.55 \frac{\text{m}}{\text{s}} \right)^2 - \left(3.72 \frac{\text{m}}{\text{s}} \right)^2 \right] \\
 &= (114 \times 10^3 \text{ Pa}) \left(\frac{1 \text{ atm}}{1.01 \times 10^5 \text{ Pa}} \right) \\
 &= \boxed{1.1 \text{ atm}}
 \end{aligned}$$

59. (a) The pressure is less because the velocity of the water is greater.

$$\begin{aligned}
 \text{(b)} \quad P_1 + \frac{1}{2}\rho v_1^2 &= P_2 + \frac{1}{2}\rho v_2^2 \\
 \Delta P &= P_2 - P_1 \\
 &= \frac{1}{2}\rho(v_1^2 - v_2^2) \\
 &= \frac{1}{2}\rho\left[v_1^2 - \left(\frac{A_1}{A_2}\right)^2 v_1^2\right] \\
 &= \frac{1}{2}\rho v_1^2\left[1 - \left(\frac{A_1}{A_2}\right)^2\right] \\
 &= \frac{1}{2}\rho v^2\left\{1 - \left[\frac{\frac{\pi}{4}d^2}{\frac{\pi}{4}\left(\frac{d}{2}\right)^2}\right]^2\right\} \\
 &= \frac{1}{2}\rho v^2(1-16) \\
 &= \boxed{-\frac{15}{2}\rho v^2}
 \end{aligned}$$

60. $\frac{\Delta V}{\Delta t} \propto r^4$ (Poiseuille's equation)

$$\left(\frac{\Delta V}{\Delta t}\right)_2 / \left(\frac{\Delta V}{\Delta t}\right)_1 = 2 = \left(\frac{r_2}{r_1}\right)^4$$

$$r_2 = (2)^{1/4} r_1 = 1.19 r_1$$

$$\frac{r_2 - r_1}{r_1} \times 100 = \left(\frac{1.19 r_1 - r_1}{r_1}\right)(100) = \boxed{19\%}$$

$$61. \text{ (a)} \quad \Delta V = \frac{(P_1 - P_2)\pi r^4 \Delta t}{8\eta L} = \frac{(450 \text{ Pa})(\pi)(2.4 \times 10^{-3} \text{ m})^4(1.0 \text{ s})}{8(0.0027 \text{ N} \cdot \text{s/m}^2)(8.5 \times 10^{-2} \text{ m})} = \boxed{26 \text{ cm}^3}$$

$$\text{(b)} \quad r_2 = 0.84 r_1$$

$$\left(\frac{\Delta V}{\Delta t}\right)_2 / \left(\frac{\Delta V}{\Delta t}\right)_1 = \left(\frac{r_2}{r_1}\right)^4 = \left(\frac{0.84 r_1}{r_1}\right)^4 = 0.50 = \frac{1}{2}$$

The flow rate is reduced by a factor of 2.

$$62. \quad \Delta P_2 r_2^4 = \Delta P_1 r_1^4$$

$$r_2 = 0.85 r_1$$

$$\Delta P_2 = \Delta P_1 \left(\frac{r_1}{r_2}\right)^4 = \Delta P_1 \left(\frac{r_1}{0.85 r_1}\right)^4 = 1.92 \Delta P_1$$

The pressure drop has increased by a factor of 1.9.

$$63. \text{ (a) } v = \frac{\left(\frac{\Delta V}{\Delta t}\right)}{A} = \frac{5.0 \times 10^{-4} \text{ m}^3/\text{s}}{\pi \left(\frac{2.5 \times 10^{-2} \text{ m}}{2}\right)^2} = \boxed{1.0 \text{ m/s}}$$

$$\text{ (b) } \Delta P = \frac{8\eta L(\Delta V / \Delta t)}{\pi r^4} = \frac{8(1.0055 \times 10^{-3} \text{ N} \cdot \text{s}/\text{m}^2)(15 \text{ m})(5.0 \times 10^{-4} \text{ m}^3/\text{s})}{\pi \left(\frac{2.5 \times 10^{-2} \text{ m}}{2}\right)^4} = \boxed{790 \text{ Pa}}$$

$$\text{ (c) } \Delta V / \Delta t \propto r^4, \text{ but } A \propto r^2, \text{ so } \Delta V / \Delta t \propto A^2$$

$$A_2 = \frac{1}{2} A_1$$

$$(\Delta V / \Delta t)_2 / (\Delta V / \Delta t)_1 = (A_2 / A_1)^2 = \left(\frac{\frac{1}{2} A_1}{A_1}\right)^2 = \frac{1}{4}$$

Volume flow rate decreases by a factor of 4.

$$v = \frac{\Delta V / \Delta t}{A}$$

$$\frac{v_2}{v_1} = \frac{(\Delta V / \Delta t)_2}{(\Delta V / \Delta t)_1} \frac{A_1}{A_2} = \left(\frac{1}{4}\right) \left(\frac{A_1}{\frac{1}{2} A_1}\right) = \frac{1}{2}$$

Water speed decreases by a factor of 2.

$$64. \quad P = P_{\text{at}} + \rho gh$$

$$2P_{\text{at}} = P_{\text{at}} + \rho gh$$

$$h = \frac{P_{\text{at}}}{\rho g} = \frac{1.01 \times 10^5 \text{ Pa}}{\left(1025 \frac{\text{kg}}{\text{m}^3}\right) \left(9.81 \frac{\text{m}}{\text{s}^2}\right)} = \boxed{10.0 \text{ m}}$$

$$65. \text{ force} = \text{area} \times \text{average pressure}$$

$$A = \pi Dh = \pi(5.2 \text{ m})(1.4 \text{ m}) = 22.87 \text{ m}^2$$

Average pressure = pressure at half-depth

$$P = \rho g \left(\frac{h}{2}\right) = \left(1000 \frac{\text{kg}}{\text{m}^3}\right) \left(9.81 \frac{\text{m}}{\text{s}^2}\right) (0.70 \text{ m}) = 6867 \text{ Pa}$$

$$F = (22.87 \text{ m}^2)(6867 \text{ Pa}) = \boxed{160 \text{ kN}}$$

$$66. \text{ (a) } T = mg$$

$$m = \frac{T}{g} = \frac{35.0 \text{ N}}{9.81 \frac{\text{m}}{\text{s}^2}} = 3.57 \text{ kg}$$

$$\Sigma F_y = 0$$

$$T + B - mg = 0$$

$$T + \rho_w Vg - mg = 0$$

$$V = \frac{mg - T}{\rho_w g} = \frac{35.0 \text{ N} - 31.1 \text{ N}}{\left(1000 \frac{\text{kg}}{\text{m}^3}\right) \left(9.81 \frac{\text{m}}{\text{s}^2}\right)} = 3.98 \times 10^{-4} \text{ m}^3$$

$$\rho_{\text{block}} = \frac{m}{V} = \frac{3.57 \text{ kg}}{3.98 \times 10^{-4} \text{ m}^3} = \boxed{8.97 \times 10^3 \text{ kg}/\text{m}^3}$$

$$\begin{aligned}
 \text{(b)} \quad \Sigma F_y &= 0 \\
 T + B - mg &= 0 \\
 T + \rho_{\text{oil}} V g - mg &= 0 \\
 \rho_{\text{oil}} &= \frac{mg - T}{Vg} \\
 &= \frac{35.0 \text{ N} - 31.8 \text{ N}}{\left(3.98 \times 10^{-4} \text{ m}^3\right) \left(9.81 \frac{\text{m}}{\text{s}^2}\right)} \\
 &= \boxed{821 \text{ kg/m}^3}
 \end{aligned}$$

$$\begin{aligned}
 67. \text{ (a)} \quad \Sigma F_y &= 0 \\
 -W + F_s &= 0 \\
 -\rho_{\text{block}} V g - kx &= 0 \\
 x &= \frac{-\rho_{\text{block}} V g}{k} \\
 &= \frac{-\left(710 \frac{\text{kg}}{\text{m}^3}\right) (0.012 \text{ m}^3) \left(9.81 \frac{\text{m}}{\text{s}^2}\right)}{540 \frac{\text{N}}{\text{m}}} \\
 &= -0.15 \text{ m}
 \end{aligned}$$

The spring is compressed 0.15 m.

$$\begin{aligned}
 \text{(b)} \quad \Sigma F_y &= 0 \\
 -W + F_s + B &= 0 \\
 -\rho_{\text{block}} V g - kx + \rho_w V g &= 0 \\
 x &= \frac{(\rho_w - \rho_{\text{block}}) V g}{k} \\
 &= \frac{\left(1000 \frac{\text{kg}}{\text{m}^3} - 710 \frac{\text{kg}}{\text{m}^3}\right) (0.012 \text{ m}^3) \left(9.81 \frac{\text{m}}{\text{s}^2}\right)}{540 \frac{\text{N}}{\text{m}}} \\
 &= 0.063 \text{ m}
 \end{aligned}$$

The spring is stretched 0.063 m.

$$\begin{aligned}
 68. \text{ (a)} \quad \Sigma F_y &= 0 \\
 -W_{\text{block}} - W_{\text{ball}} + B &= 0 \\
 -m_{\text{block}} g - m_{\text{ball}} g + \rho_w V g &= 0 \\
 V &= \frac{m_{\text{block}} + m_{\text{ball}}}{\rho_w}
 \end{aligned}$$

$$\text{Now, } m_{\text{ball}} = \rho_{\text{iron}} V_{\text{ball}} = \rho_{\text{iron}} \left(\frac{4}{3} \pi r^3 \right)$$

Substitute.

$$V = \frac{m_{\text{block}} + \frac{4}{3} \pi r^3 \rho_{\text{iron}}}{\rho_w} = \frac{1.25 \text{ kg} + \frac{4}{3} \pi (0.0122 \text{ m})^3 \left(7.86 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right)}{1000 \frac{\text{kg}}{\text{m}^3}} = \boxed{0.00131 \text{ m}^3}$$

- (b) The same total volume of water must be displaced in order to support the same total weight. Since the ball now is submerged the volume of wood submerged will decrease.

$$(c) \quad V_{\text{wood}} = V - V_{\text{ball}} = V - \frac{4}{3}\pi r^3 = 0.00131 \text{ m}^3 - \frac{4}{3}\pi(0.0122 \text{ m})^3 = \boxed{0.00130 \text{ m}^3}$$

69. Let 1 and 2 denote the conditions at the top of the straw and out in the room, respectively. Neglect changes in room air pressure due to height.

$$\begin{aligned} P_1 + \frac{1}{2}\rho_{\text{air}}v^2 &= P_2 \\ P_2 - P_1 &= \frac{1}{2}\rho_{\text{air}}v^2 \\ &= \rho_{\text{w}}gh \\ v &= \sqrt{\frac{2\rho_{\text{w}}gh}{\rho_{\text{air}}}} \\ &= \sqrt{\frac{2\left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(0.013 \text{ m})}{1.29 \frac{\text{kg}}{\text{m}^3}}} \\ &= \boxed{14 \text{ m/s}} \end{aligned}$$

70. $P_{\text{at}} = \rho_{\text{air}}gh$

$$\begin{aligned} h &= \frac{P_{\text{at}}}{\rho_{\text{air}}g} \\ &= \frac{1.01 \times 10^5 \text{ Pa}}{\left(1.29 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)} \\ &= \boxed{7.98 \text{ km} < \text{height of Mt. Everest}} \end{aligned}$$

71. (a) total force = force on base + force on annular region

$$\begin{aligned} &= P_1 A_1 + P_2 A_2 \\ &= pgh_1 A_1 + pgh_2 A_2 \\ &= pg(h_1 A_1 + h_2 A_2) \\ &= \left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)[(0.18 \text{ m})(24 \times 10^{-4} \text{ m}^2) + (0.090 \text{ m})(12 \times 10^{-4} \text{ m}^2)] \\ &= \boxed{5.3 \text{ N}} \end{aligned}$$

$$(b) \quad F = mg = \rho Vg = \rho(h_1 A_1 + h_2 A_2)g$$

72. (a) total force = force on base – upward force on annular region

$$\begin{aligned} &= P_1 A_1 - P_2 A_2 \\ &= pgh_1 A_1 - pgh_2 A_2 \\ &= pg(h_1 A_1 - h_2 A_2) \\ &= \left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)[(0.18 \text{ m})(24 \times 10^{-4} \text{ m}^2) - (0.090 \text{ m})(12 \times 10^{-4} \text{ m}^2)] \\ &= \boxed{3.2 \text{ N}} \end{aligned}$$

$$(b) \quad F = mg = \rho Vg = \rho[(h_1 - h_2)A_1 + (A_1 - A_2)h_2]g = \rho(h_1 A_1 - h_2 A_2)g$$

$$(c) \quad v = 2\sqrt{gh} = 2\sqrt{\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(0.090 \text{ m})} = \boxed{1.9 \text{ m/s}}$$

The water will rise to the top of the container.

$$73. (a) \quad P = P_{\text{at}} + \rho_w gh = 1.013 \times 10^5 \text{ Pa} + \left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(0.31 \text{ m}) = \boxed{1.04 \times 10^5 \text{ Pa}}$$

(b) The pressure increases, because the water depth increases.

$$(c) \quad P_{\text{total}} = P + \frac{mg}{A} = P + \frac{mg}{\pi r^2} = 1.043 \times 10^5 \text{ Pa} + \frac{(78 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)}{\pi(1.1 \text{ m})^2} = \boxed{1.05 \times 10^5 \text{ Pa}}$$

74. Let f = mass fraction (So, $f_{\text{gold}} + f_{\text{granite}} = 1$.)

$$\begin{aligned} \rho_{\text{rock}} &= f_{\text{granite}} \rho_{\text{granite}} + f_{\text{gold}} \rho_{\text{gold}} \\ &= (1 - f_{\text{gold}}) \rho_{\text{granite}} + f_{\text{gold}} \rho_{\text{gold}} \end{aligned}$$

$$\begin{aligned} f_{\text{gold}} &= \frac{\rho_{\text{rock}} - \rho_{\text{granite}}}{\rho_{\text{gold}} - \rho_{\text{granite}}} \\ &= \frac{\frac{m_{\text{rock}}}{V_{\text{rock}}} - \rho_{\text{granite}}}{\rho_{\text{gold}} - \rho_{\text{granite}}} \\ &= \frac{\frac{3.81 \text{ kg}}{3.55 \times 10^{-4} \text{ m}^3} - 2650 \frac{\text{kg}}{\text{m}^3}}{19.3 \times 10^3 \frac{\text{kg}}{\text{m}^3} - 2650 \frac{\text{kg}}{\text{m}^3}} \\ &= 0.485 \end{aligned}$$

$$\begin{aligned} m_{\text{gold}} &= f_{\text{gold}} m_{\text{rock}} \\ &= 0.485(3.81 \text{ kg}) \\ &= \boxed{1.85 \text{ kg}} \end{aligned}$$

$$\begin{aligned} 75. \quad P_{\text{max}} &= P_{\text{at}} + \rho_{\text{earth}} gh_{\text{max}} \\ h_{\text{max}} &= \frac{P_{\text{max}} - P_{\text{at}}}{\rho_{\text{earth}} g} \\ &= \frac{1.2 \times 10^9 \text{ Pa} - 1.01 \times 10^5 \text{ Pa}}{\left(3.0 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)} \\ &= \boxed{41 \text{ km}} \end{aligned}$$

76. (a) $\Sigma F_y = 0$
 $F_b - T - mg = 0$
 $\rho_w Vg - T - \rho_{\text{block}} Vg = 0$

$$V = \frac{T}{g(\rho_w - \rho_{\text{block}})}$$

$$= \frac{0.95 \text{ N}}{\left(9.81 \frac{\text{m}}{\text{s}^2}\right)\left(1000 \frac{\text{kg}}{\text{m}^3} - 706 \frac{\text{kg}}{\text{m}^3}\right)}$$

$$= \boxed{3.3 \times 10^{-4} \text{ m}^3}$$

(b) Since only part of the block will be immersed, the water level will drop.

(c) $\rho_{\text{block}} V_{\text{block}} g = \rho_w V_w g$

$$V_w = \left(\frac{\rho_{\text{block}}}{\rho_w}\right) V_{\text{block}}$$

$$\Delta h = \frac{V_w}{A} = \frac{\left(\frac{\rho_{\text{block}}}{\rho_w}\right) V_{\text{block}}}{A} = \frac{\left(\frac{706 \frac{\text{kg}}{\text{m}^3}}{1000 \frac{\text{kg}}{\text{m}^3}}\right)(3.29 \times 10^{-4} \text{ m}^3)}{65 \times 10^{-4} \text{ m}^2} = \boxed{3.6 \text{ cm}}$$

77. (a) $P_1 + \rho g d = P_3 + \frac{1}{2} \rho v^2$
 $P_{\text{at}} + \rho g d = P_{\text{at}} + \frac{1}{2} \rho v^2$

$$v = \boxed{\sqrt{2gd}}$$

(b) The speed of the water is the same, assuming constant pipe diameter, since $v_2 A_2 = v_3 A_3$.

78. Find the velocity at the hole using Torricelli's Law.

$$v = \sqrt{2gh} = \sqrt{2\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(0.32 \text{ m})} = 2.506 \frac{\text{m}}{\text{s}}$$

(a) $y = v_{0y}t + \frac{1}{2}a_y t^2$
 $0 = v_{0y}t + \frac{1}{2}(-g)t^2$
 $t = 0$ (trivial solution), or,

$$t = \frac{2v_{0y}}{g} = \frac{2\left(2.506 \frac{\text{m}}{\text{s}}\right)\sin 35^\circ}{9.81 \frac{\text{m}}{\text{s}^2}} = 0.293 \text{ s}$$

$$x = v_{0x}t + \frac{1}{2}a_x t^2$$

$$x = \left(2.506 \frac{\text{m}}{\text{s}}\right)(\cos 35^\circ)(0.293 \text{ s}) + 0$$

$$= \boxed{0.60 \text{ m}}$$

(b) The maximum height occurs at $t_{\text{total}}/2$.

$$y = v_{0y} \left(\frac{t_{\text{total}}}{2} \right) + \frac{1}{2} \left(-9.81 \frac{\text{m}}{\text{s}^2} \right) \left(\frac{t_{\text{total}}}{2} \right)^2 = \left(2.506 \frac{\text{m}}{\text{s}} \right) (\sin 35^\circ) \left(\frac{0.293 \text{ s}}{2} \right) - \left(4.905 \frac{\text{m}}{\text{s}^2} \right) \left(\frac{0.293 \text{ s}}{2} \right)^2 = \boxed{0.10 \text{ m}}$$

79. (a) $\Sigma F_y = 0$

$$F_b + N - mg = 0$$

$$\rho_w V g + N - mg = 0$$

$$V = \frac{mg - N}{\rho_w g}$$

$$= \frac{682 \text{ N} - 498 \text{ N}}{\left(1000 \frac{\text{kg}}{\text{m}^3} \right) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)}$$

$$= 0.01876 \text{ m}^3$$

$$V_{\text{leg}} = \frac{V}{2} = \frac{0.0188 \text{ m}^3}{2} = \boxed{9.38 \times 10^{-3} \text{ m}^3}$$

$$(b) \quad m_{\text{leg}} = \rho_{\text{leg}} V_{\text{leg}} = (1.05 \rho_w) V_{\text{leg}} = 1.05 \left(1000 \frac{\text{kg}}{\text{m}^3} \right) (0.009378 \text{ m}^3) = \boxed{9.85 \text{ kg}}$$

$$80. (a) \quad P_1 - P_2 = 8\pi\eta \frac{vL}{A}$$

$$= 8\pi\eta \frac{vL}{\frac{\pi D^2}{4}}$$

$$= \frac{32\eta vL}{D^2}$$

$$= \frac{32 \left(0.00012 \frac{\text{N}\cdot\text{s}}{\text{m}^2} \right) \left(1.2 \frac{\text{m}}{\text{s}} \right) (55 \text{ m})}{(0.052 \text{ m})^2}$$

$$= \boxed{94 \text{ Pa}}$$

$$(b) \quad \text{volume flow rate} = Av = \left(\frac{\pi D^2}{4} \right) v = \frac{\pi (0.052 \text{ m})^2 \left(1.2 \frac{\text{m}}{\text{s}} \right)}{4} = \boxed{0.0025 \text{ m}^3/\text{s}}$$

$$\begin{aligned}
 81. \quad \rho Av &= 1.5 \frac{\text{g}}{\text{s}} \\
 v &= \frac{1.5 \frac{\text{g}}{\text{s}}}{\rho A} \\
 &= \frac{1.5 \frac{\text{g}}{\text{s}}}{\rho \left(\frac{\pi D^2}{4} \right)} \\
 &= \frac{4 \left(1.5 \frac{\text{g}}{\text{s}} \right)}{\rho \pi D^2} \\
 &= \frac{4(1.5 \times 10^{-3} \frac{\text{kg}}{\text{s}})}{\left(1000 \frac{\text{kg}}{\text{m}^3} \right) \pi (0.28 \times 10^{-3} \text{ m})^2} \\
 &= 24.4 \text{ m/s}
 \end{aligned}$$

$$\Delta P = 8\pi\eta \frac{vL}{A} = \frac{32\eta vL}{D^2} = \frac{32 \left(0.00101 \frac{\text{N}\cdot\text{s}}{\text{m}^2} \right) (24.4 \frac{\text{m}}{\text{s}}) (0.032 \text{ m})}{(0.28 \times 10^{-3} \text{ m})^2} = \boxed{320 \text{ kPa}}$$

82. (a) There is no acceleration, so the force on all sides of the water is the same. The water is level.
- (b) The water tilts forward. That is, the water is deeper at the back side of the pan. To produce a forward acceleration the forward force exerted by the back side of the pan must be greater than the backward force exerted by the front side of the pan.
- (c) Apply Newton's second law.
 Assume the pan has length L and width W , and that it contains water with depth d . When accelerating the depth at the back wall will be $d + h$, while the depth at the front wall will be $d - h$. The surface is tilted at an angle θ , with $\tan \theta = \frac{2h}{W}$.

The average pressure exerted by the water on the back wall is $\frac{\rho g(d+h)}{2}$; at the front wall it is $\rho g \frac{(d-h)}{2}$.

$$F_{\text{net } x} = ma = F_b - F_f, \text{ where}$$

F_b = force exerted forward by back wall

$$= P_b A_b = \left[\rho g \frac{(d+h)}{2} \right] [L(d+h)] = \frac{\rho g L}{2} (d^2 + 2dh + h^2)$$

F_f = force exerted backward by front wall

$$= P_f A_f = \left[\rho g \frac{(d-h)}{2} \right] [L(d-h)] = \frac{\rho g L}{2} (d^2 - 2dh + h^2)$$

$$ma = \rho Va = \rho(LWd)a = \left[\frac{\rho g L}{2} (d^2 + 2dh + h^2) \right] - \left[\frac{\rho g L}{2} (d^2 - 2dh + h^2) \right]$$

$$\rho LWda = \rho g L(2dh)$$

$$\frac{2h}{W} = \frac{a}{g}$$

$$\tan \theta = \frac{2h}{W} = \frac{a}{g}$$

83. A is the horizontal cross-sectional area. Let h be the depth to which the base of the block is under the fluid. Let F_r be the restoring force generated when the block is displaced from equilibrium a distance of Δh .

$$F_r = \rho_2(\Delta V)g = \rho_2(A\Delta h)g$$

If we compare this equation to that of a mass-spring system we see that $x = \Delta h$ and $k = \rho_2 Ag$.

The mass of the block is $m = \rho_1 V = \rho_1 AH$, where H is the height of the block.

The period of a mass-spring system is $T = 2\pi\sqrt{\frac{m}{k}}$.

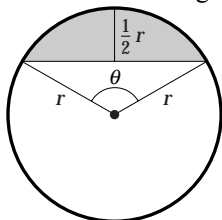
Substitute.

$$T = 2\pi\sqrt{\frac{\rho_1 AH}{\rho_2 Ag}} = \boxed{2\pi\sqrt{\frac{\rho_1 H}{\rho_2 g}}}$$

84. $A_{\text{sub}} = A_{\text{log}} - A_{\text{above water}}$

$$= \pi r^2 - \frac{1}{2}r^2(\theta - \sin \theta)$$

where θ is the angle shown below.



To find θ , note that the triangle in the figure is formed by two right triangles.

$$\cos \frac{\theta}{2} = \frac{\frac{1}{2}r}{r} = \frac{1}{2}$$

$$\theta = 2 \cos^{-1} \frac{1}{2} = 2 \left(\frac{\pi}{3} \right) = \frac{2\pi}{3}$$

$$A_{\text{sub}} = r^2 \left[\pi - \frac{1}{2} \left(\frac{2\pi}{3} - \sin \frac{2\pi}{3} \right) \right] = r^2 \left[\pi - \frac{\pi}{3} + \frac{1}{2} \left(\frac{\sqrt{3}}{2} \right) \right] = \left(\frac{2\pi}{3} + \frac{\sqrt{3}}{4} \right) r^2$$

Determine the density of the log.

$$\rho_L V_L g = \rho_w V_w g$$

$$\rho_L (A_L L) g = \rho_w (A_{\text{sub}} L) g$$

$$\begin{aligned} \rho_L &= \frac{A_{\text{sub}}}{A_L} \rho_w \\ &= \frac{\left(\frac{2\pi}{3} + \frac{\sqrt{3}}{4} \right) r^2}{\pi r^2} \rho_w \\ &= \left(\frac{2}{3} + \frac{\sqrt{3}}{4\pi} \right) \left(1000 \frac{\text{kg}}{\text{m}^3} \right) \\ &= \boxed{804.5 \text{ kg/m}^3} \end{aligned}$$

85. Assume that the hollow part of the sphere contains a vacuum.

$$\begin{aligned}
 \rho_{\text{sphere}} &= \frac{m_{\text{sphere}}}{V_{\text{sphere}}} \\
 &= \frac{\rho_g V_g}{V_{\text{sphere}}} \\
 \rho_{\text{sub}} V_{\text{sub}} g &= \rho_{\text{sphere}} V_{\text{sphere}} g \\
 V_{\text{sub}} &= \frac{\rho_{\text{sphere}} V_{\text{sphere}}}{\rho_{\text{sub}}} \\
 &= \frac{\rho_g V_g V_{\text{sphere}}}{\rho_{\text{sub}} V_{\text{sphere}}} \\
 &= \frac{\rho_g}{1.5 \rho_g} V_g \\
 &= 0.67 V_g
 \end{aligned}$$

The fraction of the shell that is submerged is 0.67.

86. In air:

$$\Sigma F_y = 0$$

$$N - mg = 0$$

$$N = mg$$

In water:

$$\Sigma F_y = 0$$

$$N + F_b - mg = 0$$

$$\frac{mg}{2} + \rho_w V g - mg = 0$$

$$\rho_w V = \frac{m}{2}$$

$$\rho_w V = \frac{\rho_{\text{geode}} V}{2}$$

$$\rho_{\text{geode}} = 2 \rho_w$$

Let f = the fraction by volume.

$$\rho_{\text{geode}} = f_{\text{solid}} \rho_{\text{solid}} + (1 - f_{\text{solid}}) \rho_{\text{air}}$$

We can drop the second term on the right side of this equation since $\rho_{\text{air}} \ll \rho_{\text{solid}}$.

$$\rho_{\text{geode}} = f_{\text{solid}} \rho_{\text{solid}}$$

$$f_{\text{solid}} = \frac{\rho_{\text{geode}}}{\rho_{\text{solid}}} = \frac{2 \rho_w}{\rho_{\text{solid}}} = \frac{2 \left(1000 \frac{\text{kg}}{\text{m}^3} \right)}{2500 \frac{\text{kg}}{\text{m}^3}} = 0.80$$

$$f_{\text{air}} = 1 - f_{\text{solid}} = 1 - 0.80 = \span style="border: 1px solid black; padding: 0 2px;">0.20$$

87. From Torricelli's Law, $v = \sqrt{2g(d-h)}$.

$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$$

$$0 = h + 0 - \frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2h}{g}}$$

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 = 0 + \sqrt{2g(d-h)}\sqrt{\frac{2h}{g}} + 0 = 2\sqrt{(d-h)h}$$

88. From Problem 87,

$$x = 2[(d-h)h]^{1/2}$$

$$x_{\text{top}} = 2[(d-3.6 \text{ m})(3.6 \text{ m})]^{1/2}$$

$$x_{\text{bottom}} = 2[(d-0.80 \text{ m})(0.80 \text{ m})]^{1/2}$$

$$x_{\text{top}} = x_{\text{bottom}}$$

$$2[(d-3.6 \text{ m})(3.6 \text{ m})]^{1/2} = 2[(d-0.80 \text{ m})(0.80 \text{ m})]^{1/2}$$

$$(d-3.6 \text{ m})(3.6 \text{ m}) = (d-0.80 \text{ m})(0.80 \text{ m})$$

$$d = \boxed{4.4 \text{ m}}$$

89. Determine the mass of the box.

$$m_{\text{box}}g = \rho_w V_w g$$

$$m_{\text{box}} = \rho_w (0.45V_{\text{box}})$$

$$= 0.45\rho_w L^3$$

For the box-plus-water system to sink, its density must be the same as or greater than that of water.

$$\rho_{\text{box+water}} = \frac{m_{\text{box}} + m_w}{V_{\text{box}}} = \rho_w$$

$$m_w = \rho_w V_{\text{box}} - m_{\text{box}}$$

$$= \rho_w L^3 - 0.45\rho_w L^3$$

$$= 0.55\rho_w L^3$$

$$= 0.55\left(1000 \frac{\text{kg}}{\text{m}^3}\right)(0.23 \text{ m})^3$$

$$= \boxed{6.7 \text{ kg}}$$