Physics 2A
Chapter 13 HW Solutions

Chapter 13
Conceptual Questions: 3, 6, 15, 28
Problems: 5, 8, 14, 25, 32, 33, 44, 46, 50, 56

Q13.3. Reason: If the chunk is heavy (dense) enough to sink in water you would put the chunk into a known volume of water in a graduated cylinder and note the rise; this would give the volume of the chunk. A simple measurement of the chunk's mass on a pan balance would then allow you to use $\rho = m/V$.
Assess: If the chunk floats in water then you would have to find a way to submerse it to find the volume.

Q13.6. Reason: The pressure at a depth of 10 m is

$$p = p_0 + \rho g h = 1.013\times10^5\text{ Pa} + (1000\text{ kg/m}^3)(9.80\text{ m/s}^2)(10\text{ m}) = 2\times10^5\text{ Pa}$$

This is almost twice atmospheric pressure. It will be difficult for Tom to inhale.
Assess: Note that atmospheric pressure is approximately the gauge pressure at a depth of 10 m of water.

Q13.15. Reason: The fraction of the object below the surface of the liquid is the object's density as a fraction of the liquid's density (if we can ignore the density of the air). Since A has the greatest fraction below the surface it is the most dense. The least dense (B) floats with the largest fraction of its volume above the fluid level (the smallest fraction below the liquid level).

$$\rho_\text{A} > \rho_\text{C} > \rho_\text{B}$$

Assess: You've heard that only 10% of an iceberg is visible above the surface of the ocean. That means 90% of the iceberg is below the surface. Therefore the density of ice is 90% the density of seawater. Verify this by looking in Table 13.1 and finding on the Web the density of ice, $\rho_\text{ice} = 917\text{ kg/m}^3$.

Q13.28. Reason: (a) From the equation of continuity, 13.12, as the cross-sectional area of the pipe increases the velocity of the fluid decreases. The area at point 1 is the smallest, so the velocity is the greatest. The area is larger at point 2, so the velocity is smaller there. At point 3, the area is the same as point 2, so the velocity is the same as at point 2. The area at point 4 is the largest, so the velocity is the smallest there. The speeds in order of highest to lowest are 1, 2 and 3, 4.
From Bernoulli's equation, the pressure will be highest when the velocity is lowest. The pressures in order from highest to lowest are, 4, 3 and 2, 1.
Assess: The continuity equation holds for incompressible fluid, so the answer to **(a)** is the same whether the fluid is viscous or not.

P13.5. Prepare: The densities of gasoline and water are given in Table 13.1.
Solve: (a) The total mass is

$$m_\text{total} = m_\text{gasoline} + m_\text{water} = 0.050\text{ kg} + 0.050\text{ kg} = 0.100\text{ kg}$$

The total volume is

$$V_\text{total} = V_\text{gasoline} + V_\text{water} = \frac{m_\text{gasoline}}{\rho_\text{gasoline}} + \frac{m_\text{water}}{\rho_\text{water}} = \frac{0.050\text{kg}}{680\text{kg/m}^3} + \frac{0.050\text{ kg}}{1000\text{kg/m}^3} = 1.235\times10^{-4}\text{ m}^3$$

$$\Rightarrow \rho_\text{avg} = \frac{m_\text{total}}{V_\text{total}} = \frac{0.100\text{ kg}}{1.235\times10^{-4}\text{ m}^3} = 810\text{ kg/m}^3$$

(b) The average density is calculated as follows:

$$m_{\text{total}} = m_{\text{gasoline}} + m_{\text{water}} = \rho_{\text{water}} V_{\text{water}} + \rho_{\text{gasoline}} V_{\text{gasoline}}$$

$$\Rightarrow \rho_{\text{avg}} = \frac{\rho_{\text{water}} V_{\text{water}} + \rho_{\text{gasoline}} V_{\text{gasoline}}}{V_{\text{water}} + V_{\text{gasoline}}} = \frac{(50\ \text{cm}^3)(1000\ \text{kg/m}^3 + 680\ \text{kg/m}^3)}{100\ \text{cm}^3} = 840\ \text{kg/m}^3$$

Assess: The above average densities are between those of gasoline and water, and are reasonable.

P13.8. Prepare: The density of sea water is 1030 kg/m^3. Also, $1\ \text{atm} = 1.013 \times 10^5\ \text{Pa}$.

Solve: The pressure below sea level can be found from Equation 13.5 as follows:

$$p = p_0 + \rho g d = 1.013 \times 10^5\ \text{Pa} + (1030\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(1.1 \times 10^4\ \text{m})$$
$$= 1.013 \times 10^5\ \text{Pa} + 1.1103 \times 10^8\ \text{Pa} = 1.11 \times 10^8\ \text{Pa} = 1100\ \text{atm}$$

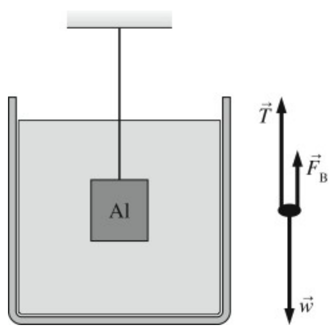
Assess: The pressure deep in the ocean is very large.

P13.14. Prepare: The pressure required will be the atmospheric pressure exerted by the air on the water in the container subtracted by the pressure exerted by the column of water.

Solve: $$p = p_{\text{atm}} - \rho g h = 1.013 \times 10^5\ \text{Pa} - (1000\,\text{kg/m}^3)(9.80\,\text{m/s}^2)(2.0\,\text{m}) = 8.2 \times 10^4\ \text{Pa}$$

Assess: The principle here is similar to the principle in a barometer.

P13.25. Prepare: The buoyant force on the aluminum block is given by Archimedes' principle. The density of aluminum and ethyl alcohol are $\rho_{\text{Al}} = 2700$ kg/m^3 and $\rho_{\text{ethyl alcohal}} = 790$ kg/m^3. The buoyant force F_B and the tension due to the string act vertically up, and the weight of the aluminum block acts vertically down. The block is submerged, so the volume of displaced fluid equals V_{Al}, the volume of the block.



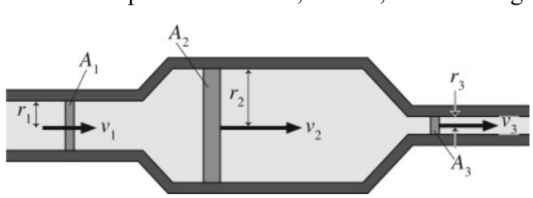
Solve: The aluminum block is in static equilibrium, so

$$\Sigma F_y = F_B + T - w = 0\ \text{N} \Rightarrow \rho_f V_{\text{Al}} g + T - \rho_{\text{Al}} V_{\text{Al}} g = 0\ \text{N} \Rightarrow T = V_{\text{Al}} g(\rho_{\text{Al}} - \rho_f)$$
$$T = (100 \times 10^{-6}\ \text{m}^3)(9.80\ \text{m/s}^2)(2700\ \text{kg/m}^3 - 790\ \text{kg/m}^3) = 1.9\ \text{N}$$

where we have used the conversion $100\ \text{cm}^3 = 100 \times (10^{-2}\ \text{m})^3 = 10^{-4}\ \text{m}^3$.

Assess: The weight of the aluminum block is $\rho_{\text{Al}} V_{\text{Al}} g = 2.7\ \text{N}$. A similar order of magnitude for T is reasonable.

P13.32. Prepare: The pipe itself is a flow tube, so the equation of continuity applies. Note that A_1, A_2, and A_3 and v_1, v_2, and v_3 are the cross-sectional areas and the speeds in the first, second, and third segments of the pipe.



Solve: **(a)** The equation of continuity is

$$A_1v_1 = A_2v_2 = A_3v_3 \Rightarrow \pi r_1^2 v_1 = \pi r_2^2 v_2 = \pi r_3^2 v_3 \Rightarrow r_1^2 v_1 = r_2^2 v_2 = r_3^2 v_3$$
$$\Rightarrow (0.005\text{ m})^2(4.0\text{ m/s}) = (0.01\text{ m})^2 v_2 = (0.0025\text{ m})^2 v_3$$
$$\Rightarrow v_2 = \left(\frac{0.005\text{ m}}{0.01\text{ m}}\right)^2(4.0\text{ m/s}) = 1.0\text{ m/s} \qquad v_3 = \left(\frac{0.005\text{ m}}{0.0025\text{ m}}\right)^2(4.0\text{ m/s}) = 16\text{ m/s}$$

(b) The volume flow rate through the pipe is

$$Q = A_1v_1 = \pi(0.005\text{ m})^2(4.0\text{ m/s}) = 3.1\times10^{-4}\text{ m}^3\text{/s}$$

Assess: Since most of us do not have a good feel for flow rate in m^3/s, let's look at this value in L/s. A flow rate $3.1\times10^{-4}\text{ m}^3\text{/s}$ is equal to 0.31L/s. This is a small but reasonable flow rate for a 0.5-cm diameter pipe.

P13.33. Prepare: Please refer to Equation 13.14 (Bernoulli's equation). Treat the oil as an ideal fluid obeying Bernoulli's equation. Consider the path connecting point 1 in the lower pipe with point 2 in the upper pipe a streamline.
Solve: Bernoulli's equation is

$$p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 = p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 \Rightarrow p_2 = p_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right) + \rho g(y_1 - y_2)$$

Using $p_1 = 200\text{ kPa} = 2.00\times10^5\text{ Pa}$, $\rho = 900\text{ kg/m}^3$, $y_2 - y_1 = 10.0\text{ m}$, $v_1 = 2.0\text{ m/s}$, and $v_2 = 3.0\text{ m/s}$, we get $p_2 = 1.1\times10^5\text{ Pa} = 110$ kPa.
Assess: We expect the pressure at point 2 to be less than the pressure at point 1. If this were not the case, the fluid would not flow from point 1 to point 2.

P13.44. Prepare: Equation 13.5 gives the pressure at the hole.
Solve: The pressure at the hole is

$$p = p_0 + \rho g h = (101.3\text{ kPa}) + (1000\text{ kg/m}^3)(9.80\text{ m/s}^2)(2.5\text{ m}) = 125.8\text{ kPa}$$

where additional significant figures have been kept in the intermediate result. The force on the Dutch boy's finger is $F = (125.8\times10^3\text{ Pa})(75\times10^{-6}\text{ m}^2) = 9.4\text{ N}$.
Assess: This result seems reasonable. The pressure is not much higher than atmospheric pressure and the hole has a small area.

P13.46. Prepare: The tire flattens until the pressure force against the ground balances the upward normal force of the ground on the tire. The area of the tire in contact with the road is $A = (0.15\text{ m})(0.13\text{ m}) = 0.0195\text{ m}^2$.
Solve: The normal force on each tire is

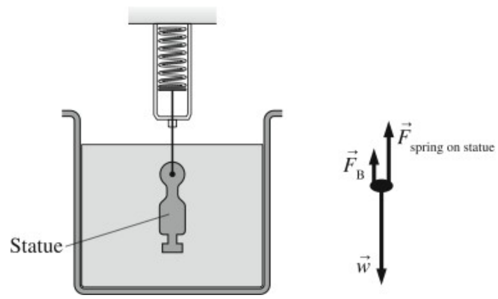
$$n = \frac{w}{4} = \frac{(1500\text{ kg})(9.8\text{ m/s}^2)}{4} = 3675\text{ N}$$

Thus, the pressure inside each tire is

$$p_{\text{inside}} = \frac{n}{A} = \frac{3675\text{ N}}{0.0195\text{ m}^2} = 188{,}500\text{ Pa} = 1.86\text{ atm}\times\frac{14.7\text{ psi}}{1\text{ atm}} = 27\text{ psi}$$

Assess: A pressure slightly lower than 30 psi is what is expected.

P13.50. Prepare: The buoyant force on the ceramic statue is given by Archimedes' principle.



Solve: The statue's weight is the 28.4 N registered on the scale in air. In water, the weight of the statue is balanced by the sum of the buoyant force F_B and the spring's force on the statue. That is,

$$w_{\text{statue}} = F_B + F_{\text{spring on statue}} \Rightarrow 28.4\text{ N} = \rho_w V_{\text{statue}} g + 17.0\text{ N} \Rightarrow V_{\text{statue}} = \frac{11.4\text{ N}}{g\rho_w} = \frac{m_{\text{statue}}}{\rho_{\text{statue}}}$$

$$\Rightarrow \rho_{\text{statue}} = \frac{(m_{\text{statue}} g)\rho_w}{(11.4\text{ N})} = \frac{(28.4\text{ N})(1000\text{ kg/m}^3)}{(11.4\text{ N})} = 2500\text{ kg/m}^3$$

Assess: Many solids have a density around 2500 kg/m^3, so the value is reasonable.

P13.56. Prepare: Treat the air as an ideal fluid obeying Bernoulli's equation.
Solve: **(a)** The pressure above the roof is lower due to the higher velocity of the air.
(b) Bernoulli's equation, with $y_{\text{inside}} \approx y_{\text{outside}}$, is

$$p_{\text{inside}} = p_{\text{outside}} + \frac{1}{2}\rho_{\text{air}} v^2 \Rightarrow \Delta p = \frac{1}{2}\rho_{\text{air}} v^2 = \frac{1}{2}(1.28\text{ kg/m}^3)\left(\frac{130\times 1000\text{ m}}{3600\text{ s}}\right)^2 = 835\text{ Pa}$$

(c) The force on the roof is $(\Delta p)A = (835\text{ Pa})(6.0\text{ m}\times 15.0\text{ m}) = 7.5\times 10^4\text{ N}$. The roof will blow outward (up), because pressure inside the house is greater than pressure on the top of the roof.
Assess: This problem helps one understand why high winds cause extensive roof damage.