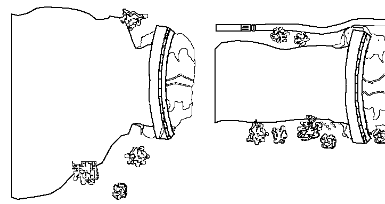
CHAPTER 15

ANSWERS TO QUESTIONS

Q15.1 In the ocean, the ship floats due to the buoyant force from *salt water*. Salt water is denser than fresh water. As the ship is pulled up the river, the buoyant force from the fresh water in the river is not sufficient to support the weight of the ship, and it sinks.

Q15.2 Both the same. The force on the back of each dam is the average pressure of the water times the area of the dam. If both reservoirs are equally deep, the force is the same.



Q15.3 If the tube were to fill up to the height of several stories of the building, the pressure at the bottom of the depth of the tube of fluid would be very large according to Equation 15.4. This pressure is much larger than that due to the inward elastic forces of the balloon on the water. As a result, water is pushed into the balloon from the tube. As more water is added to the tube, more water continues to enter the balloon, stretching it thin. For a typical balloon, the pressure at the bottom of the tube can become greater than the pressure at which the balloon material will rupture, so the balloon will simply fill with water and expand until it bursts. Blaise Pascal splintered strong barrels by this method.

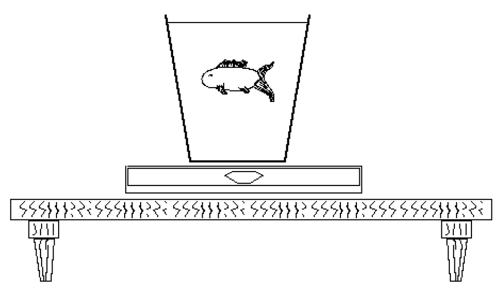
Q15.4 No. The somewhat lighter barge will float higher in the water.

Q15.5 The level of the pond falls. This is because the anchor displaces more water while in the boat. A floating object displaces a volume of water whose weight is equal to the weight of the object. A submerged object displaces a volume of water equal to the volume of the object. Because the density of the anchor is greater than that of water, a volume of water that weighs the same as the anchor will be greater than the volume of the anchor.

Q15.6 Because the weight depends upon the total volume of glass. The pressure depends only on the depth.

Q15.7 The submarine would stop if the density of the surrounding water became the same as the average density of the submarine. Unfortunately, because the water is almost incompressible, this will be much deeper than the crush depth of the submarine.

Q15.8 No. The propulsive force of the fish causes the scale reading to fluctuate about the weight of bucket, water, and fish.



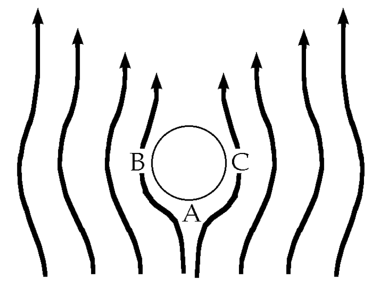
Q15.9 According to Archimedes's principle, the magnitude of buoyant force on the ship is equal to the weight of the water displaced by the ship. Because the density of salty ocean water is greater than fresh lake water, less ocean water needs to be displaced to enable the ship to float. Thus, the boat floats higher in the ocean than in the inland lake.

Q15.10 Exactly the same. Buoyancy equals density of water times volume displaced.

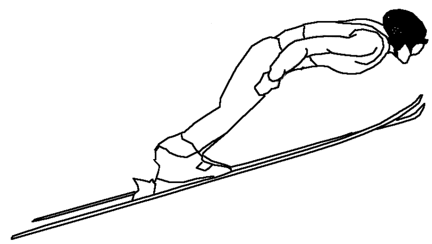
Q15.11 The water level on the side of the glass stays the same. The floating ice cube displaces its own weight of liquid water, and so does the liquid water into which it melts.

Q15.12 At lower elevation the water pressure is greater because pressure increases with increasing depth below the water surface in the reservoir (or water tower). The penthouse apartment is not so far below the water surface. The pressure behind a closed faucet is weaker there and the flow weaker from an open faucet.

Q15.13 The relatively slow-moving air below the ball at A exerts enough pressure to support the weight of the ball. If the ball wanders off to one side – say to the right in the picture – the rapidly-moving air on the other side at B exerts less pressure, and the air at C pushes the ball back toward the center of the stream.



Q15.14 The ski–jumper gives her body the shape of an airfoil. She deflects downward the air stream as it rushes past and it deflects her upward by Newton's third law. The air exerts on her a lift force, giving her a higher and longer trajectory. To say it in different words, the pressure on her back is less than the pressure on her front.



Q15.15 The glass has higher density than water. The air inside has lower density. The total weight of the bottle can be less than the weight of an equal volume of water.

Q15.16 Breathing in makes your volume greater and increases the buoyant force on you.

Q15.17 The excess pressure is transmitted undiminished throughout the container. It will compress air inside the wood. The water driven into the wood raises its average density and makes if float lower in the water. Add some thumbtacks to reach neutral buoyancy and you can make the wood sink or rise at will by subtly squeezing a large clear–plastic soft–drink bottle. Bored with graph paper and proving his own existence, René Descartes invented this toy or trick.

Q15.18 The air in your lungs, the blood in your arteries and veins, and the protoplasm in each cell exert nearly the same pressure, so that the wall of your chest can be in equilibrium.

Q15.19 Like the ball, the balloon will remain in front of you. It will not bob up to the ceiling. Air pressure will be no higher at the floor of the car than at the ceiling. The balloon will experience no buoyant force. You might equally well switch off gravity.

Q15.20 Styrofoam is a little more dense than the air, so the first ship floats lower in the water.

Q15.21 We suppose the compound object floats. In both orientations it displaces its own weight of water, so it displaces equal volumes of water. The water level in the tub will be unchanged when the object is turned over. Now the steel is underwater and the water exerts on the steel a buoyant force that was not present when the steel was on top surrounded by air. Thus, slightly less wood will be below the water line on the block. It will appear to float higher.

Q15.22 Look at Figures 15.13 and 15.18. A breeze from any direction speeds up to go over the mound and the air pressure drops. Air then flows through the burrow from the lower to the upper entrance.

Q15.23 Regular cola contains a considerable mass of dissolved sugar. Its density is higher than that of water. Diet cola contains a very small mass of artificial sweetener and has nearly the same density as water. The low–density air in the can has a bigger effect than the thin aluminum shell, so the can of diet cola floats.

PROBLEM SOLUTIONS

***15.1** $M = \rho_{\text{iron}} V = \left(7860\ \text{kg/m}^3\right)\left[\frac{4}{3}\pi(0.0150\ \text{m})^3\right]$

$M = \boxed{0.111\ \text{kg}}$

15.2 $\rho = \dfrac{M}{V} = \dfrac{0.5}{185 \times 10^{-6}} = 2.70 \times 10^3\ \text{kg/m}^3$

$\boxed{\text{No.}}$ The crown is made of aluminum.

15.3 $P = \dfrac{F}{A} = \dfrac{50.0(9.80)}{\pi\left(0.500 \times 10^{-2}\right)^2} = \boxed{6.24 \times 10^6\ \text{N/m}^2}$

***15.4** Let F_g be its weight. Then each tire supports $F_g / 4$,

so $P = \dfrac{F}{A} = \dfrac{F_g}{4A}$

yielding $F_g = 4AP = 4\left(0.0240\ \text{m}^2\right)\left(200 \times 10^3\ \text{N/m}^2\right) = \boxed{1.92 \times 10^4\ \text{N}}$

15.5 The Earth's surface area is $4\pi R^2$. The force pushing inward over this area amounts to

$$F = P_0 A = P_0\left(4\pi R^2\right)$$

This force is the weight of the air:

$$F_g = mg = P_0\left(4\pi R^2\right)$$

so the mass of the air is

$$m = \frac{P_0\left(4\pi R^2\right)}{g} = \frac{\left(1.013 \times 10^5\ \text{N/m}^2\right)\left[4\pi\left(6.37 \times 10^6\ \text{m}\right)^2\right]}{9.80\ \text{m/s}^2} = \boxed{5.27 \times 10^{18}\ \text{kg}}$$

***15.6** (a) $P = P_0 + \rho g h = 1.013 \times 10^5 \text{ Pa} + \left(1024 \text{ kg/m}^3\right)\left(9.80 \text{ m/s}^2\right)(1000 \text{ m})$

$$P = \boxed{1.01 \times 10^7 \text{ Pa}}$$

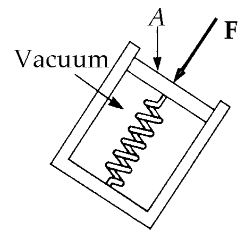
(b) The gauge pressure is the difference in pressure between the water outside and the air inside the submarine, which we suppose is at 1.00 atmosphere.

$$P_{\text{gauge}} = P - P_0 = \rho g h = 1.00 \times 10^7 \text{ Pa}$$

The resultant inward force on the porthole is then

$$F = P_{\text{gauge}} A = 1.00 \times 10^7 \text{ Pa}\left[\pi(0.150 \text{ m})^2\right] = \boxed{7.09 \times 10^5 \text{ N}}$$

15.7 $F_{el} = F_{\text{fluid}}$ or $kx = \rho g h A$



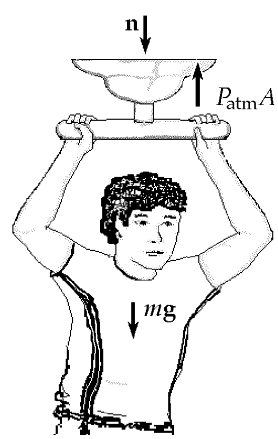
and $h = \dfrac{kx}{\rho g A}$

$$h = \frac{\left(1000 \text{ N/m}^2\right)\left(5.00 \times 10^{-3} \text{ m}\right)}{\left(10^3 \text{ kg/m}^3\right)\left(9.80 \text{ m/s}^2\right)\left[\pi\left(1.00 \times 10^{-2} \text{ m}\right)^2\right]} = \boxed{1.62 \text{ m}}$$

15.8 Since the pressure is the same on both sides, $\dfrac{F_1}{A_1} = \dfrac{F_2}{A_2}$

In this case, $\dfrac{15000}{200} = \dfrac{F_2}{3.00}$ or $F_2 = \boxed{225 \text{ N}}$

15.9 $F_g = 80.0 \text{ kg}\left(9.80 \text{ m/s}^2\right) = 784 \text{ N}$



When the cup barely supports the student, the normal force of the ceiling is zero and the cup is in equilibrium.

$$F_g = F = PA = \left(1.013 \times 10^5 \text{ Pa}\right)A$$

$$A = \frac{F_g}{P} = \frac{784}{1.013 \times 10^5} = \boxed{7.74 \times 10^{-3} \text{ m}^2}$$

***15.10** (a) Suppose the "vacuum cleaner" functions as a high–vacuum pump. The air below the brick will exert on it a lifting force

$$F = PA = 1.013\times10^{5}\ \text{Pa}\left[\pi\left(1.43\times10^{-2}\ \text{m}\right)^{2}\right] = \boxed{65.1\ \text{N}}$$

(b) The octopus can pull the bottom away from the top shell with a force that could be no larger than

$$F = PA = \left(P_0+\rho gh\right)A = \left[1.013\times10^{5}\ \text{Pa} + \left(1030\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)(32.3\ \text{m})\right]\left[\pi\left(1.43\times10^{-2}\ \text{m}\right)^{2}\right]$$

$$F = \boxed{275\ \text{N}}$$

15.11 The pressure on the bottom due to the water is $P_b = \rho gz = 1.96\times10^{4}\ \text{Pa}$

So, $F_b = P_bA = \boxed{5.88\times10^{6}\ \text{N}}$

On each end, $F = \overline{P}A = 9.80\times10^{3}\ \text{Pa}\left(20.0\ \text{m}^2\right) = \boxed{196\ \text{kN}}$

On the side, $F = \overline{P}A = 9.80\times10^{3}\ \text{Pa}\left(30.0\ \text{m}^2\right) = \boxed{588\ \text{kN}}$

***15.12** (a) We imagine the superhero to produce a perfect vacuum in the straw. Take point 1 at the water surface in the basin and point 2 at the water surface in the straw:

$$P_1 + \rho gy_1 = P_2 + \rho gy_2$$

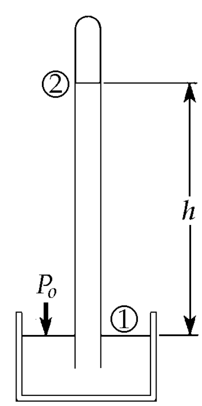
$$1.013\times10^{5}\ \text{N/m}^2 + 0 = 0 + \left(1000\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)y_2 \qquad y_2 = \boxed{10.3\ \text{m}}$$

(b) No atmosphere can lift the water in the straw through $\boxed{\text{zero}}$ height difference.

15.13 $P_0 = \rho gh$

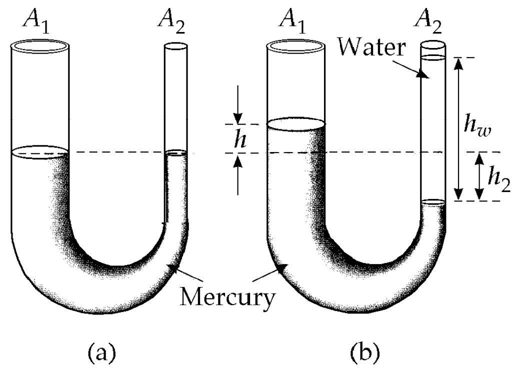
$$h = \frac{P_0}{\rho g} = \frac{1.013\times10^{5}\ \text{Pa}}{\left(0.984\times10^{3}\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)} = \boxed{10.5\ \text{m}}$$

$\boxed{\text{Some alcohol and water will evaporate.}}$



15.14 (a) Using the definition of density, we have

$$h_w = \frac{m_{\text{water}}}{A_2\rho_{\text{water}}} = \frac{100 \text{ g}}{5.00 \text{ cm}^2\left(1.00 \text{ g/cm}^3\right)} = \boxed{20.0 \text{ cm}}$$



(b) Sketch (b) at the right represents the situation after the water is added. A volume (A_2h_2) of mercury has been displaced by water in the right tube. The additional volume of mercury now in the left tube is A_1h. Since the total volume of mercury has not changed,

$$A_2h_2 = A_1h \quad \text{or} \quad h_2 = \frac{A_1}{A_2}h \qquad (1)$$

At the level of the mercury–water interface in the right tube, we may write the absolute pressure as:

$$P = P_0 + \rho_{\text{water}}gh_w$$

The pressure at this same level in the left tube is given by $P = P_0 + \rho_{\text{Hg}}g(h + h_2) = P_0 + \rho_{\text{water}}gh_w$

which, using equation (1) above, reduces to $\rho_{\text{Hg}}h\left[1 + \frac{A_1}{A_2}\right] = \rho_{\text{water}}h_w$

or

$$h = \frac{\rho_{\text{water}}h_w}{\rho_{\text{Hg}}\left(1 + \frac{A_1}{A_2}\right)}$$

Thus, the level of mercury has risen a distance of $h = \frac{\left(1.00 \text{ g/cm}^3\right)(20.0 \text{ cm})}{\left(13.6 \text{ g/cm}^3\right)\left(1 + \frac{10.0}{5.00}\right)} = \boxed{0.490 \text{ cm}}$

above the original level.

15.15 $\Delta P_0 = \rho g \Delta h = -2.66 \times 10^3 \text{ Pa}:$ $\quad P = P_0 + \Delta P_0 = (1.013 - 0.0266) \times 10^5 \text{ Pa} = \boxed{0.986 \times 10^5 \text{ Pa}}$

***15.16** (a) $P = P_0 + \rho gh$

The gauge pressure is $P - P_0 = \rho gh = 1000 \text{ kg}\left(9.8 \text{ m/s}^2\right)(0.160 \text{ m}) = \boxed{1.57 \text{ kPa}}$

$$= 1.57 \times 10^3 \text{ Pa}\left(\frac{1 \text{ atm}}{1.013 \times 10^5 \text{ Pa}}\right) = \boxed{0.0155 \text{ atm}}$$

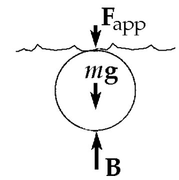
It would lift a mercury column to height $h = \frac{P - P_0}{\rho g} = \frac{1568 \text{ Pa}}{\left(13600 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)} = \boxed{11.8 \text{ mm}}$

(b) Increased pressure of the cerebrospinal fluid will raise the level of the fluid in the spinal tap.

(c) Blockage of the fluid within the spinal column or between the skull and the spinal column would prevent the fluid level from rising.

15.17 At equilibrium $\Sigma F = 0$ or $F_{app} + mg = B$

where B is the buoyant force.



The applied force, $F_{app} = B - mg$

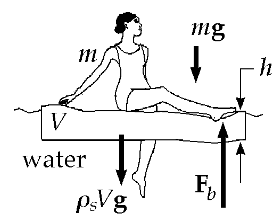
where $B = \text{Vol}(\rho_{\text{water}})g$

and $m = (\text{Vol})\rho_{\text{ball}}$

So, $F_{app} = (\text{Vol})g(\rho_{\text{water}} - \rho_{\text{ball}}) = \frac{4}{3}\pi r^3 g(\rho_{\text{water}} - \rho_{\text{ball}})$

$$F_{app} = \frac{4}{3}\pi\left(1.90 \times 10^{-2} \text{ m}\right)^3\left(9.80 \text{ m/s}^2\right)\left(10^3 \text{ kg/m}^3 - 84.0 \text{ kg/m}^3\right) = \boxed{0.258 \text{ N}}$$

15.18 $F_g = (m + \rho_s V)g$ must be equal to $F_b = \rho_w V g$



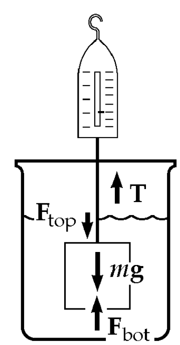
Since $V = Ah$, $m + \rho_s Ah = \rho_w Ah$

and $A = \boxed{\dfrac{m}{(\rho_w - \rho_s)h}}$

15.19 (a) $P = P_0 + \rho g h$

Taking $P_0 = 1.013 \times 10^5 \text{ N/m}^2$ and $h = 5.00$ cm,

we find $P_{\text{top}} = 1.0179 \times 10^5 \text{ N/m}^2$



For $h = 17.0$ cm, we get $P_{\text{bot}} = 1.0297 \times 10^5 \text{ N/m}^2$

Since the areas of the top and bottom are $A = (0.100 \text{ m})^2 = 10^{-2} \text{ m}^2$

we find $F_{\text{top}} = P_{\text{top}}A = \boxed{1.0179 \times 10^3 \text{ N}}$

and $F_{\text{bot}} = \boxed{1.0297 \times 10^3 \text{ N}}$

(b) $T + B - Mg = 0$

where $B = \rho_w V g = \left(10^3 \text{ kg/m}^3\right)\left(1.20 \times 10^{-3} \text{ m}^3\right)\left(9.80 \text{ m/s}^2\right) = 11.8 \text{ N}$

and $Mg = 10.0(9.80) = 98.0 \text{ N}$

Therefore, $T = Mg - B = 98.0 - 11.8 = \boxed{86.2 \text{ N}}$

(c) $F_{\text{bot}} - F_{\text{top}} = (1.0297 - 1.0179) \times 10^3 \text{ N} = \boxed{11.8 \text{ N}}$

which is equal to B found in part (b).

15.20 Consider spherical balloons of radius 12.5 cm containing helium at STP and immersed in air at 0°C and 1 atm. If the rubber envelope has mass 5.00 g, the upward force on each is

$$B - F_{g,\text{He}} - F_{g,env} = \rho_{\text{air}} V g - \rho_{\text{He}} V g - m_{env} g$$

$$F_{up} = (\rho_{\text{air}} - \rho_{\text{He}})\left(\tfrac{4}{3}\pi r^3\right)g - m_{env} g$$

$$F_{up} = \left[(1.29 - 0.179)\ \text{kg/m}^3\right]\left[\tfrac{4}{3}\pi(0.125\ \text{m})^3\right]\left(9.80\ \text{m/s}^2\right) - 5.00\times10^{-3}\ \text{kg}\left(9.80\ \text{m/s}^2\right) = 0.0401\ \text{N}$$

If your weight (including harness, strings, and submarine sandwich) is

$$70.0\ \text{kg}\left(9.80\ \text{m/s}^2\right) = 686\ \text{N}$$

you need this many balloons: $\dfrac{686\ \text{N}}{0.0401\ \text{N}} = 17\,000\ \boxed{\sim 10^4}$

15.21 (a) According to Archimedes, $B = \rho_{\text{water}} V_{\text{water}} g = (1.00\ \text{g/cm}^3)\left[20.0\times20.0\times(20.0-h)\right]g$

But $B = \text{Weight of block} = mg = \rho_{\text{wood}} V_{\text{wood}} g = \left(0.650\ \text{g/cm}^3\right)(20.0\ \text{cm})^3 g$

$$0.650(20.0)^3 g = 1.00(20.0)(20.0)(20.0-h)g$$

$20.0 - h = 20.0(0.650)$ so $h = 20.0(1-0.650) = \boxed{7.00\ \text{cm}}$

(b) $B = F_g + Mg$ where $M =$ mass of lead

$$1.00(20.0)^3 g = 0.650(20.0)^3 g + Mg$$

$$M = (1.00-0.650)(20.0)^3 = 0.350(20.0)^3 = 2800\ \text{g} = \boxed{2.80\ \text{kg}}$$

***15.22** Let A represent the horizontal cross-sectional area of the rod, which we presume to be constant. The rod is in equilibrium:

$\Sigma F_y = 0$: $-mg + B = 0 = -\rho_0 V_{\text{whole rod}} g + \rho_{\text{fluid}} V_{\text{immersed}} g$

$$\rho_0 A L g = \rho A (L-h) g$$

The density of the liquid is $\rho = \dfrac{\rho_0 L}{L-h}$

15.23 The balloon stops rising when $(\rho_{\text{air}} - \rho_{\text{He}})gV = Mg$ and $(\rho_{\text{air}} - \rho_{\text{He}})V = M$,

Therefore, $V = \dfrac{M}{\rho_{\text{air}} - \rho_{\text{He}}} = \dfrac{400}{1.25e^{-1} - 0.180}$ $V = \boxed{1430\ \text{m}^3}$

***15.24** Constant velocity implies zero acceleration, which means that the submersible is in equilibrium under the gravitational force, the upward buoyant force, and the upward resistance force:

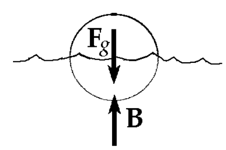
$$\Sigma F_y = ma_y = 0 \qquad -\left(1.20\times10^4\ \text{kg} + m\right)g + \rho_w g V + 1100\ \text{N} = 0$$

where m is the mass of the added water and V is the sphere's volume.

$$1.20\times10^4\ \text{kg} + m = 1.03\times10^3\left[\tfrac{4}{3}\pi(1.50)^3\right] + \frac{1100\ \text{N}}{9.8\ \text{m/s}^2}$$

so $$m = \boxed{2.67\times10^3\ \text{kg}}$$

15.25 $B = F_g$



$$\rho_{H_2O} g \frac{V}{2} = \rho_{\text{sphere}} g V$$

$$\rho_{\text{sphere}} = \tfrac{1}{2}\rho_{H_2O} = \boxed{500\ \text{kg/m}^3}$$

$$\rho_{\text{glycerin}} g\left(\tfrac{4}{10}V\right) - \rho_{\text{sphere}} g V = 0$$

$$\rho_{\text{glycerin}} = \tfrac{10}{4}\left(500\ \text{kg/m}^3\right) = \boxed{1250\ \text{kg/m}^3}$$

***15.26** Let ℓ represent the length below water at equilibrium and M the tube's mass:

$\Sigma F_y = 0$: $$-Mg + \rho\pi r^2 \ell g = 0$$

Now with any excursion x from equilibrium: $$-Mg + \rho\pi r^2(\ell - x)g = Ma$$

Subtracting the equilibrium equation gives: $$-\rho\pi r^2 g x = Ma$$

$$a = -\left(\rho\pi r^2 g / M\right)x = -\omega^2 x$$

The opposite direction and direct proportionality of a to x imply SHM with angular frequency

$$\omega = \sqrt{\rho\pi r^2 g / M}$$

$$T = \frac{2\pi}{\omega} = \boxed{\frac{2}{r}\sqrt{\frac{\pi M}{\rho g}}}$$

15.27 Volume flow rate $= A_1 v_1 = A_2 v_2$

$$\frac{20.0\text{ L}}{60.0\text{ s}}\left(\frac{1000\text{ cm}^3}{1\text{ L}}\right) = \pi(1.00\text{ cm})^2 v_{\text{hose}} = \pi(0.500\text{ cm})^2 v_{\text{nozzle}}$$

(a) $v_{\text{hose}} = \dfrac{333\text{ cm}^3/\text{s}}{3.14\text{ cm}^2} = \boxed{106\text{ cm/s}}$

(b) $v_{\text{nozzle}} = \dfrac{333\text{ cm}^3/\text{s}}{0.785\text{ cm}^2} = \boxed{424\text{ cm/s}}$

15.28 By Bernoulli's equation,

$$8.00\times10^4\text{ N/m}^2 + \tfrac{1}{2}(1000)v^2 = 6.00\times10^4\text{ N/m}^2 + \tfrac{1}{2}(1000)16v^2$$

$$2.00\times10^4\text{ N/m}^2 = \tfrac{1}{2}(1000)15v^2$$

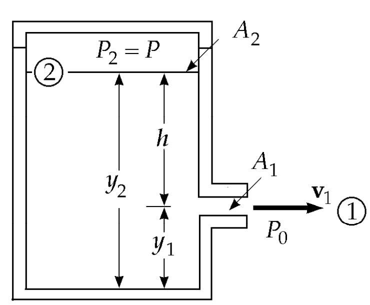
$$v = 1.63\text{ m/s}$$

$$\frac{dm}{dt} = \rho A v = 1000\pi\left(5.00\times10^{-2}\right)^2(1.63\text{ m/s}) = \boxed{12.8\text{ kg/s}}$$

15.29 (a) $\mathcal{P} = \dfrac{\Delta E}{\Delta t} = \dfrac{\Delta mgh}{\Delta t} = \left(\dfrac{\Delta m}{\Delta t}\right)gh = Rgh$

(b) $\mathcal{P}_{\text{EL}} = 0.85\left(8.5\times10^5\right)(9.8)(87) = \boxed{616\text{ MW}}$

15.30 If we assume the tank is large in cross section compared to the hole ($A_2 >> A_1$), then the fluid will be approximately at rest at the top, point 2. Applying Bernoulli's equation to points 1 and 2, and noting that at the hole



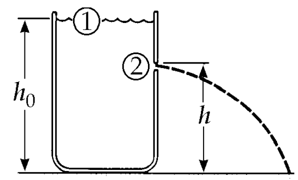
$$P_1 = P_0$$

we get

$$P_0 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = P + \rho g y_2$$

But $y_2 - y_1 = h$, and so this reduces to $\quad v_1 = \sqrt{\dfrac{2(P - P_0)}{\rho} + 2gh}$

15.31 Apply Bernoulli's equation between the top surface and the exiting stream.



$$P_0 + 0 + \rho g h = P_0 + \tfrac{1}{2}\rho v_x^2 + \rho g h$$

$$v_x^2 = 2g(h_0 - h) \qquad \therefore\ v_x = \sqrt{2g(h_0 - h)}$$

$$x = v_x t: \qquad y = h = \tfrac{1}{2} g t^2$$

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

and $x = v_x\sqrt{\dfrac{2h}{g}} = \sqrt{2g(h_0 - h)}\sqrt{\dfrac{2h}{g}}$: $\qquad x = \boxed{2\sqrt{h(h_0 - h)}}$

15.32 As in problem 31, apply Bernoulli's equation between the top surface and the exiting stream.

$$P_0 + 0 + \rho g h_0 = P_0 + \tfrac{1}{2}\rho v_x^2 + \rho g h: \qquad v_x^2 = 2g(h_0 - h)$$

$$\therefore v_x = \sqrt{2g(h_0 - h)}$$

$x = v_x t,\quad h = \tfrac{1}{2} g t^2$ and $t = \sqrt{\dfrac{2h}{g}}$ $\qquad x = \sqrt{2g(h_0 - h)}\sqrt{\dfrac{2h}{g}} = \sqrt{4h(h_0 - h)}$

(a) Maximize x with respect to h. $\qquad \dfrac{dx}{dh} = 0$: $\qquad \dfrac{dx}{dh} = \dfrac{\tfrac{1}{2}(4h_0 - 8h)}{\sqrt{4h(h_0 - h)}} = 0$

when $\qquad \boxed{h = \dfrac{h_0}{2}}$

(b) For $h = \dfrac{h_0}{2}$, $\quad v_x = \sqrt{g h_0}$, and $\qquad t = \sqrt{\dfrac{h_0}{g}}$

then $\qquad x = v_x t = \boxed{h_0}$

15.33 (a) Between sea surface and clogged hole: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

$$1 \text{ atm } + 0 + \left(1030 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)(2 \text{ m}) = P_2 + 0 + 0 \qquad P_2 = 1 \text{ atm} + 20.2 \text{ kPa}$$

The air on the back of his hand pushes opposite the water, so the net force on his hand is

$$F = PA = \left(20.2 \times 10^3 \text{ N/m}^2\right)\left(\frac{\pi}{4}\right)\left(1.2 \times 10^{-2} \text{ m}\right)^2 \qquad F = \boxed{2.28 \text{ N}}$$

(b) Now, Bernoulli's theorem is

$$1 \text{ atm} + 0 + 20.2 \text{ kPa} = 1 \text{ atm} + \frac{1}{2}\left(1030 \text{ kg/m}^3\right)v_2^2 + 0 \qquad v_2 = 6.26 \text{ m/s}$$

The volume rate of flow is $A_2 v_2 = \frac{\pi}{4}\left(1.2 \times 10^{-2} \text{ m}\right)^2(6.26 \text{ m/s}) = 7.08 \times 10^{-4} \text{ m}^3/\text{s}$

One acre–foot is $4047 \text{ m}^2 \times 0.3048 \text{ m} = 1234 \text{ m}^3$

Requiring $\dfrac{1234 \text{ m}^3}{7.08 \times 10^{-4} \text{ m}^3/\text{s}} = \boxed{1.74 \times 10^6 \text{ s}} = 20.2 \text{ days}$

15.34 (a) Suppose the flow is very slow: $\left(P + \frac{1}{2}\rho v^2 + \rho g y\right)_{\text{river}} = \left(P + \frac{1}{2}\rho v^2 + \rho g y\right)_{\text{rim}}$

$$P + 0 + \rho g(564 \text{ m}) = 1 \text{ atm} + 0 + \rho g(2096 \text{ m})$$

$$P = 1 \text{ atm} + \left(1000 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)(1532 \text{ m}) = \boxed{1 \text{ atm} + 15.0 \text{ MPa}}$$

(b) The volume flow rate is $4500 \text{ m}^3/\text{d} = Av = \dfrac{\pi d^2 v}{4}$

$$v = \left(4500 \text{ m}^3/\text{d}\right)\left(\frac{1 \text{ d}}{86\,400 \text{ s}}\right)\left(\frac{4}{\pi(0.150 \text{ m})^2}\right) = \boxed{2.95 \text{ m/s}}$$

(c) Imagine the pressure as applied to stationary water at the bottom of the pipe:

$$\left(P + \frac{1}{2}\rho v^2 + \rho g y\right)_{\text{bottom}} = \left(P + \frac{1}{2}\rho v^2 + \rho g y\right)_{\text{top}}$$

$$P + 0 = 1 \text{ atm} + \frac{1}{2}\left(1000 \text{ kg/m}^3\right)(2.95 \text{ m/s})^2 + 1000 \text{ kg}\left(9.8 \text{ m/s}^2\right)(1532 \text{ m})$$

$$P = 1 \text{ atm} + 15.0 \text{ MPa} + 4.34 \text{ kPa}$$

The additional pressure is $\boxed{4.34 \text{ kPa}}$

15.35 (a) For upward flight of a water–drop projectile from geyser vent to fountain–top, $v_{yf}^2 = v_{yi}^2 + 2a_y\Delta y$

Then $0 = v_i^2 + 2(-9.80\ \text{m/s}^2)(+40.0\ \text{m})$ and $v_i = \boxed{28.0\ \text{m/s}}$

(b) Between geyser vent and fountain–top: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

Air is so low in density that very nearly $P_1 = P_2 = 1\ \text{atm}$

Then, $\frac{1}{2}v_i^2 + 0 = 0 + (9.80\ \text{m/s}^2)(40.0\ \text{m})$

$v_1 = \boxed{28.0\ \text{m/s}}$

(c) Between the chamber and the fountain–top: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

$$P_1 + 0 + (1000\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(-175\ \text{m}) = P_0 + 0 + (1000\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(+40.0\ \text{m})$$

$$P_1 - P_0 = (1000\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(215\ \text{m}) = \boxed{2.11\ \text{MPa}}$$

15.36 $P_1 + \dfrac{\rho v_1^2}{2} = P_2 + \dfrac{\rho v_2^2}{2}$ (Bernoulli equation), $v_1 A_1 = v_2 A_2$ where $\dfrac{A_1}{A_2} = 4$

$\Delta P = P_1 - P_2 = \dfrac{\rho}{2}(v_2^2 - v_1^2) = \dfrac{\rho}{2}v_1^2\left(\dfrac{A_1^2}{A_2^2} - 1\right)$ and $\Delta P = \dfrac{\rho v_1^2}{2}15 = 21000\ \text{Pa}$

$v_1 = 2.00\ \text{m/s}$; $v_2 = 4v_1 = 8.00\ \text{m/s}$:

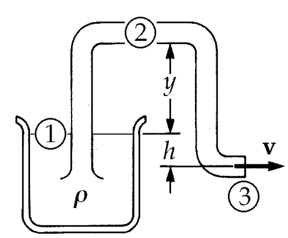
The volume flow rate is $v_1 A_1 = \boxed{2.51\times10^{-3}\ \text{m}^3/\text{s}}$

15.37 $Mg = (P_1 - P_2)A$ for a balanced condition $\dfrac{16\,000(9.80)}{A} = 7.00\times10^4 - P_2$

where $A = 80.0\ \text{m}^2$, $\therefore\ P_2 = 7.0\times10^4 - 0.196\times10^4 = \boxed{6.80\times10^4\ \text{Pa}}$

15.38 (a) $P_0 + \rho g h + 0 = P_0 + 0 + \frac{1}{2}\rho v_3^2$ $v_3 = \sqrt{2gh}$

If $h = 1.00\ \text{m}$, $v_3 = \boxed{4.43\ \text{m/s}}$



(b) $P + \rho g y + \frac{1}{2}\rho v_2^2 = P_0 + 0 + \frac{1}{2}\rho v_3^2$

Since $v_2 = v_3$, $P = P_0 - \rho g y$

Since $P \ge 0$, $y \le \dfrac{P_0}{\rho g} = \dfrac{1.013\times10^5\ \text{Pa}}{(10^3\ \text{kg/m}^3)(9.8\ \text{m/s}^2)} = \boxed{10.3\ \text{m}}$

***15.39** Take points 1 and 2 in the air just inside and outside the window pane.

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

$$P_0 + 0 = P_2 + \tfrac{1}{2}\left(1.30\text{ kg/m}^3\right)(11.2\text{ m/s})^2 \qquad P_2 = P_0 - 81.5\text{ Pa}$$

(a) The total force exerted by the air is outward,

$$P_1 A - P_2 A = P_0 A - P_0 A + \left(81.5\text{ N/m}^2\right)(4\text{ m})(1.5\text{ m}) = \boxed{489\text{ N outward}}$$

(b) $P_1 A - P_2 A = \tfrac{1}{2}\rho v_2^2 A = \tfrac{1}{2}\left(1.30\text{ kg/m}^3\right)(22.4\text{ m/s})^2(4\text{ m})(1.5\text{ m}) = \boxed{1.96\text{ kN outward}}$

***15.40** In the reservoir, the gauge pressure is $\Delta P = \dfrac{2.00\text{ N}}{2.50\times10^{-5}\text{ m}^2} = 8.00\times10^4\text{ Pa}$

From the equation of continuity: $A_1 v_1 = A_2 v_2$

$\left(2.50\times10^{-5}\text{ m}^2\right)v_1 = \left(1.00\times10^{-8}\text{ m}^2\right)v_2 \qquad v_1 = \left(4.00\times10^{-4}\right)v_2$

Thus, v_1^2 is negligible in comparison to v_2^2.

Then, from Bernoulli's equation: $(P_1 - P_2) + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = \tfrac{1}{2}\rho v_2^2 + \rho g y_2$

$$8.00\times10^4\text{ Pa} + 0 + 0 = 0 + \tfrac{1}{2}\left(1000\text{ kg/m}^3\right)v_2^2$$

$$v_2 = \sqrt{\frac{2\left(8.00\times10^4\text{ Pa}\right)}{1000\text{ kg/m}^3}} = \boxed{12.6\text{ m/s}}$$

***15.41** The iceberg floats in equilibrium

$\Sigma F_y = 0$: $\qquad -F_g + B = 0$

$0 = -m_{\text{iceberg}}g + \rho_{\text{fluid}}V_{\text{immersed}}g \qquad \rho_{\text{ice}}V_{\text{iceberg}} = \rho_{\text{fluid}}V_{\text{immersed}}$

$$\frac{V_{\text{immersed}}}{V_{\text{iceberg}}} = \frac{\rho_{\text{ice}}}{\rho_{\text{fluid}}} = \frac{0.917\times10^3\text{ kg/m}^3}{1.03\times10^3\text{ kg/m}^3} = 0.890$$

The fraction of the volume above the water line is $1 - 0.890 = 0.110 = 11.0\%$

(b) With lower density, more fresh water must be displaced to support the iceberg. A $\boxed{\text{smaller}}$ fraction is above the water line

$$\frac{V_{\text{immersed}}}{V_{\text{iceberg}}} = \frac{\rho_{\text{ice}}}{\rho_{\text{fluid}}} = \frac{0.917\times10^3\text{ kg/m}^3}{1.00\times10^3\text{ kg/m}^3} = 0.917$$

The fraction exposed is $1 - 0.917 = \boxed{8.3\%}$

***15.42** The weight of the additional water displaced is equal to the weight of the passengers:

$\rho_{\text{fluid}} \Delta V_{\text{immersed}} g = \Delta m g$ $\qquad\qquad$ $\left(1.03 \times 10^3 \text{ kg/m}^3\right)(0.0100 \text{ m})A = 2205(75 \text{ kg})$

$$A = \frac{1.65 \times 10^5 \text{ kg}}{10.3 \text{ kg/m}^2} = \boxed{1.61 \times 10^4 \text{ m}^2}$$

***15.43** (a) $\theta = \dfrac{s}{r} = \dfrac{15 \text{ m}}{0.25 \text{ m}} = \boxed{60.0 \text{ rad}}$

(b) Let T represent the tension in the rope. Define the positive y axis as pointing down.

For the anchor: $\qquad (2000 \text{ kg})\left(9.8 \text{ m/s}^2\right) - T = (2000 \text{ kg})(a)$

For the reel: $\qquad \Sigma\tau = I\alpha = \frac{1}{2} MR^2 \dfrac{a}{R}$

$T(0.25 \text{ m}) = \dfrac{1}{2}(300 \text{ kg})(0.25 \text{ m})^2 \left(\dfrac{a}{0.25 \text{ m}}\right)$ $\qquad T = (150 \text{ kg})a$

Substituting, $\qquad 19\,600 \text{ N} - (150 \text{ kg})a = (2000 \text{ kg})a$

$$a = \frac{19\,600 \text{ N}}{2150 \text{ kg}} = \boxed{9.12 \text{ m/s}^2}$$

(c) The water exerts a buoyant force on the anchor,

$$B = \rho_{\text{fluid}} V g = \rho_{\text{fluid}} \left(\frac{m}{\rho_{\text{iron}}}\right) g = \left(1.03 \times 10^3 \text{ kg/m}^3\right)\left(\frac{2000 \text{ kg}}{7.86 \times 10^3 \text{ kg/m}^3}\right)\left(9.8 \text{ m/s}^2\right) = 2570 \text{ N}$$

Now for the anchor, $\Sigma F_y = m a_y$: $\qquad 19\,600 \text{ N} - T - 2500 \text{ N} - 2570 \text{ N} = (2000 \text{ kg})(a)$

while again for the reel $\qquad T = (150 \text{ kg})a$

So $\qquad a = \dfrac{19\,600 \text{ N} - 2500 \text{ N} - 2570 \text{ N}}{2150 \text{ kg}} = \boxed{6.76 \text{ m/s}^2}$

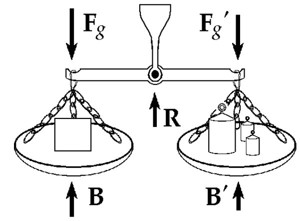
(d) $\tau = Tr = 150 \text{ kg}\left(6.76 \text{ m/s}^2\right)(0.25 \text{ m}) = \boxed{253 \text{ N} \cdot \text{m}}$

15.44 Assume $v_{\text{inside}} \cong 0$

$$P + 0 + 0 = 1 \text{ atm} + \tfrac{1}{2}(1000)(30.0)^2 + 1000(9.80)(0.500)$$

$$P_{\text{gauge}} = P - 1 \text{ atm} = 4.50 \times 10^5 + 4.90 \times 10^3 = \boxed{455 \text{ kPa}}$$

15.45 The "balanced" condition is one in which the apparent weight of the body equals the apparent weight of the weights. This condition can be written as:



$$F_g - B = F_g{}' - B'$$

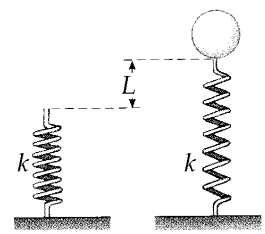
where B and B' are the buoyant forces on the body and weights respectively. The buoyant force experienced by an object of volume V in air equals:

$$\text{Buoyant force} = (\text{Volume of object})\rho_{\text{air}}g$$

so we have $\quad B = V\rho_{\text{air}}g \quad$ and $\quad B' = \left(\dfrac{F_g{}'}{\rho g}\right)\rho_{\text{air}}g$

Therefore, $\quad F_g = F_g{}' + \left(V - \dfrac{F_g{}'}{\rho g}\right)\rho_{\text{air}}g$

15.46 At equilibrium, $\Sigma F_y = 0$: $\quad B - F_{\text{spring}} - F_{g,\text{He}} - F_{g,\text{balloon}} = 0$



giving $\quad F_{\text{spring}} = kL = B - (m_{\text{He}} + m_{\text{balloon}})g$

But $\quad B = \text{weight of displaced air} = \rho_{\text{air}}Vg$

and $\quad m_{\text{He}} = \rho_{\text{He}}V$

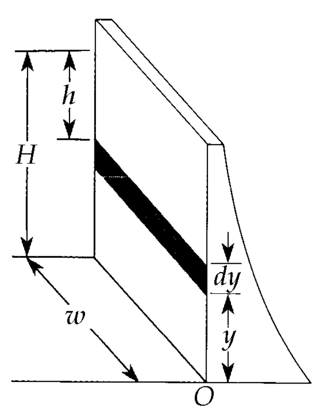
Therefore, we have: $\quad kL = \rho_{\text{air}}Vg - \rho_{\text{He}}Vg - m_{\text{balloon}}g$

or $\quad L = \dfrac{(\rho_{\text{air}} - \rho_{\text{He}})V - m_{\text{balloon}}}{k}g$

From the data given, $\quad L = \dfrac{(1.29\text{ kg/m}^3 - 0.180\text{ kg/m}^3)5.00\text{ m}^3 - 2.00\times10^{-3}\text{ kg}}{90.0\text{ N/m}}(9.80\text{ m/s}^2)$

Thus, this gives $\quad L = \boxed{0.604\text{ m}}$

15.47 The torque is $\quad \tau = \int d\tau = \int r\,dF$



From the figure $\quad \tau = \int_0^H y[\rho g(H-y)w\,dy] = \boxed{\frac{1}{6}\rho gwH^3}$

The total force is given as $\frac{1}{2}\rho gwH^2$

If this were applied at a height y_{eff} such that the torque remains unchanged, we have

$\frac{1}{6}\rho gwH^3 = y_{eff}\left[\frac{1}{2}\rho gwH^2\right] \quad$ and $\quad y_{eff} = \boxed{\frac{1}{3}H}$

15.48 $P = \rho g h$ $\qquad 1.013 \times 10^5 = 1.29(9.80)h$

$h = \boxed{8.01 \text{ km}}$ $\qquad$ For Mt. Everest, $\quad 29\,300 \text{ ft} = 8.88 \text{ km}$ $\boxed{\text{Yes}}$

***15.49** Looking at the top scale and the iron block:

$T_1 + B = F_{g,\text{Fe}}$ $\qquad$ where $\qquad B = \rho_0 V_{\text{Fe}} g = \rho_0 \left(\frac{m_{\text{Fe}}}{\rho_{\text{Fe}}}\right) g$

is the buoyant force exerted on the iron block by the oil.

Thus, $\qquad T_1 = F_{g,\text{Fe}} - B = m_{\text{Fe}} g - \rho_0 \left(\frac{m_{\text{Fe}}}{\rho_{\text{Fe}}}\right) g$

or $\qquad T_1 = \boxed{\left(1 - \frac{\rho_0}{\rho_{\text{Fe}}}\right) m_{\text{Fe}} g}$ is the reading on the top scale.

Now, consider the bottom scale, which exerts an upward force of T_2 on the beaker–oil–iron combination.

$\Sigma F_y = 0$: $\qquad T_1 + T_2 - F_{g,\text{beaker}} - F_{g,\text{oil}} - F_{g,\text{Fe}} = 0$

$$T_2 = F_{g,\text{beaker}} + F_{g,\text{oil}} + F_{g,\text{Fe}} - T_1 = (m_b + m_0 + m_{\text{Fe}})g - \left(1 - \frac{\rho_0}{\rho_{\text{Fe}}}\right) m_{\text{Fe}} g$$

or $\qquad T_2 = \boxed{\left[m_b + m_0 + \left(\frac{\rho_0}{\rho_{\text{Fe}}}\right) m_{\text{Fe}}\right] g}$ is the reading on the bottom scale.

***15.50** Let $m = \rho V$ represent the mass of the copper cylinder. The original tension in the wire is $T_1 = mg = \rho V g$. The water exerts a buoyant force $\rho_{\text{water}} \left(\frac{V}{2}\right) g$ on the cylinder, to reduce the tension to

$$T_2 = \rho V g - \rho_{\text{water}} \left(\frac{V}{2}\right) g = (\rho - \rho_{\text{water}}/2) V g.$$

The speed of a wave on the string changes from $\sqrt{T_1/\mu}$ to $\sqrt{T_2/\mu}$. The frequency changes from

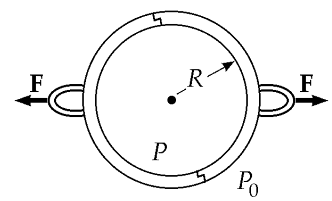
$$f_1 = \frac{v_1}{\lambda} = \sqrt{\frac{T_1}{\mu}} \frac{1}{\lambda} \qquad \text{to} \qquad f_2 = \sqrt{\frac{T_2}{\mu}} \frac{1}{\lambda}$$

where we assume $\lambda = 2L$ is constant.

Then $\qquad \frac{f_2}{f_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{\rho - \rho_{\text{water}}/2}{\rho}} = \sqrt{\frac{8.92 - 1.00/2}{8.92}}$

$$f_2 = 300 \text{ Hz} \sqrt{\frac{8.42}{8.92}} = \boxed{291 \text{ Hz}}$$

15.51 (a) The pressure on the surface of the two hemispheres is constant at all points, and the force on each element of surface area is directed along the radius of the hemispheres. The applied force along the axis must balance the force on the "effective" area, which is the projection of the actual surface onto a plane perpendicular to the x axis,



$$A = \pi R^2$$

Therefore, $$F = \boxed{(P_0 - P)\pi R^2}$$

(b) For the values given $$F = (P_0 - 0.100P_0)\left[\pi(0.300\text{ m})^2\right] = 0.254P_0 = \boxed{2.58\times 10^4\ \text{N}}$$

15.52 The incremental version of $P - P_0 = \rho g y$ is $$dP = -\rho g dy$$

We assume that the density of air is proportional to pressure, or $$\frac{P}{\rho} = \frac{P_0}{\rho_0}$$

Combining these two equations we have $$dP = -P\frac{\rho_0}{P_0}gdy$$

$$\int_{P_0}^{P}\frac{dP}{P} = -g\frac{\rho_0}{P_0}\int_0^h dy$$

and integrating gives $$\ln\left(\frac{P}{P_0}\right) = -\frac{\rho_0 gh}{P_0}$$

so where $\alpha = \rho_0 g / P_0$, $$P = P_0 e^{-\alpha h}$$

15.53 Energy for the fluid-Earth system is conserved.

$(K+U)_i + \Delta E_{\text{mech}} = (K+U)_f$: $$0 + \frac{mgL}{2} + 0 = \tfrac{1}{2}mv^2 + 0$$

$$v = \sqrt{gL} = \sqrt{2.00\text{ m}(9.8\text{ m/s}^2)} = \boxed{4.43\text{ m/s}}$$

15.54 Let s stand for the edge of the cube, h for the depth of immersion, ρ_{ice} stand for the density of the ice, ρ_w stand for density of water, and ρ_a stand for density of the alcohol.

(a) According to Archimedes's principle, at equilibrium we have

$$\rho_{\text{ice}} g s^3 = \rho_w g h s^2 \Rightarrow h = s\frac{\rho_{\text{ice}}}{\rho_w}$$

With $\rho_{\text{ice}} = 0.917 \times 10^3 \text{ kg/m}^3$

$\rho_w = 1.00 \times 10^3 \text{ kg/m}^3$

and $s = 20.0 \text{ mm}$

we get $h = 20.0(0.917) = 18.34 \text{ mm} \cong \boxed{18.3 \text{ mm}}$

(b) We assume that the top of the cube is still above the alcohol surface. Letting h_a stand for the thickness of the alcohol layer, we have

$$\rho_a g s^2 h_a + \rho_w g s^2 h_w = \rho_{\text{ice}} g s^3 \qquad \text{so} \qquad h_w = \left(\frac{\rho_{\text{ice}}}{\rho_w}\right)s - \left(\frac{\rho_a}{\rho_w}\right)h_a$$

With $\rho_a = 0.806 \times 10^3 \text{ kg/m}^3$

and $h_a = 5.00 \text{ mm}$

we obtain $h_w = 18.34 - 0.806(5.00) = 14.31 \text{ mm} \cong \boxed{14.3 \text{ mm}}$

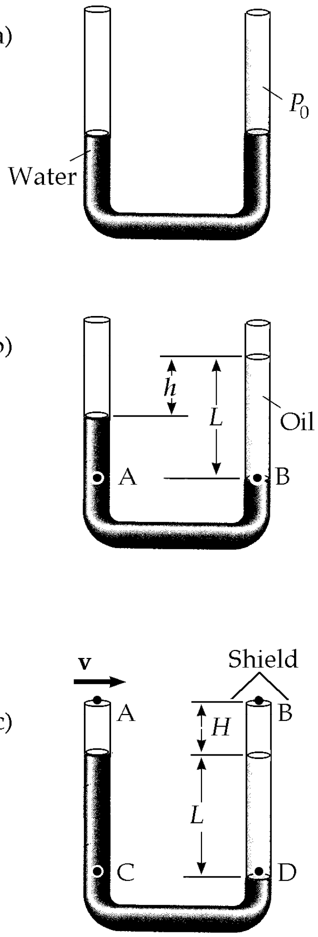
(c) Here $h_w' = s - h_a'$, so Archimedes's principle gives

$$\rho_a g s^2 h_a' + \rho_w g s^2 (s - h_a') = \rho_{\text{ice}} g s^3 \Rightarrow \rho_a h_a' + \rho_w (s - h_a') = \rho_{\text{ice}} s$$

$$h_a' = s\frac{(\rho_w - \rho_{\text{ice}})}{(\rho_w - \rho_a)} = 20.0\frac{(1.000 - 0.917)}{(1.000 - 0.806)} = 8.557 \cong \boxed{8.56 \text{ mm}}$$

***15.55** **Note**: Variation of atmospheric pressure with altitude is included in this solution. Because of the small distances involved, this effect is unimportant in the final answers.

(a) (b) (c)



(a) Consider the pressure at points A and B in part (b) of the figure:

Using the left tube: $P_A = P_{\text{atm}} + \rho_a gh + \rho_w g(L - h)$ where the second term is due to the variation of air pressure with altitude.

Using the right tube: $P_B = P_{\text{atm}} + \rho_0 gL$

But Pascal's principle says that $P_A = P_B$.

Therefore, $\quad P_{\text{atm}} + \rho_0 gL = P_{\text{atm}} + \rho_a gh + \rho_w g(L - h)$

or $\quad (\rho_w - \rho_a)h = (\rho_w - \rho_0)L$, giving

$$h = \left(\frac{\rho_w - \rho_0}{\rho_w - \rho_a}\right)L = \left(\frac{1000 - 750}{1000 - 1.29}\right)5.00\text{ cm} = \boxed{1.25\text{ cm}}$$

(b) Consider part (c) of the diagram showing the situation when the air flow over the left tube equalizes the fluid levels in the two tubes. First, apply Bernoulli's equation to points A and B ($y_A = y_B$, $v_A = v$, and $v_B = 0$).

This gives: $P_A + \frac{1}{2}\rho_a v^2 + \rho_a g y_A = P_B + \frac{1}{2}\rho_a (0)^2 + \rho_a g y_B$

and since $y_A = y_B$, this reduces to: $P_B - P_A = \frac{1}{2}\rho_a v^2 \qquad (1)$

Now consider points C and D, both at the level of the oil–water interface in the right tube. Using the variation of pressure with depth in static fluids, we have:

$$P_C = P_A + \rho_a gH + \rho_w gL \qquad \text{and} \qquad P_D = P_B + \rho_a gH + \rho_0 gL$$

But Pascal's principle says that $P_C = P_D$. Equating these two gives:

$$P_B + \rho_a gH + \rho_0 gL = P_A + \rho_a gH + \rho_w gL \qquad \text{or} \qquad P_B - P_A = (\rho_w - \rho_0)gL \qquad (2)$$

Substitute equation (1) for $P_B - P_A$ into (2) to obtain $\quad \frac{1}{2}\rho_a v^2 = (\rho_w - \rho_0)gL$

or $\quad v = \sqrt{\dfrac{2gL(\rho_w - \rho_0)}{\rho_a}} = \sqrt{2(9.80\text{ m/s}^2)(0.0500\text{ m})\left(\dfrac{1000 - 750}{1.29}\right)}$

$v = \boxed{13.8\text{ m/s}}$

***15.56** (a) The flow rate, Av, as given may be expressed as follows:

$$25.0 \text{ liters}/30.0 \text{ s} = 0.833 \text{ liters}/\text{s} = 833 \text{ cm}^3/\text{s}$$

The area of the faucet tap is $\pi \text{ cm}^2$, so we can find the velocity as

$$v = \frac{\text{flow rate}}{A} = \frac{833 \text{ cm}^3/\text{s}}{\pi \text{ cm}^2} = 265 \text{ cm/s} = \boxed{2.65 \text{ m/s}}$$

(b) We choose point 1 to be in the entrance pipe and point 2 to be at the faucet tap. $A_1v_1 = A_2v_2$ gives $v_1 = 0.295$ m/s. Bernoulli's equation is:

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

and gives $P_1 - P_2 = \tfrac{1}{2}\left(10^3 \text{ kg/m}^3\right)\left[(2.65 \text{ m/s})^2 - (0.295 \text{ m/s})^2\right] + \left(10^3 \text{ kg/m}^3\right)\left(9.80 \text{ m/s}^2\right)(2.00 \text{ m})$

or $P_{\text{gauge}} = P_1 - P_2 = \boxed{2.31 \times 10^4 \text{ Pa}}$

***15.57** (a) Since the upward buoyant force is balanced by the weight of the sphere,

$$m_1 g = \rho V g = \rho\left(\tfrac{4}{3}\pi R^3\right)g$$

In this problem, $\rho = 0.78945 \text{ g/cm}^3$ at 20.0°C, and $R = 1.00$ cm so we find:

$$m_1 = \rho\left(\tfrac{4}{3}\pi R^3\right) = \left(0.78945 \text{ g/cm}^3\right)\left[\tfrac{4}{3}\pi(1.00 \text{ cm})^3\right] = \boxed{3.307 \text{ g}}$$

(b) Following the same procedure as in part (a), with $\rho' = 0.78097 \text{ g/cm}^3$ at 30.0°C, we find:

$$m_2 = \rho'\left(\tfrac{4}{3}\pi R^3\right) = \left(0.78097 \text{ g/cm}^3\right)\left[\tfrac{4}{3}\pi(1.00 \text{ cm})^3\right] = \boxed{3.271 \text{ g}}$$

(c) When the first sphere is resting on the bottom of the tube,

$n + B = F_{g1} = m_1 g$, where n is the normal force.

Since $B = \rho' V g$,

$$n = m_1 g - \rho' V g = \left[3.307 \text{ g} - \left(0.78097 \text{ g/cm}^3\right)(1.00 \text{ cm})^3\right] 980 \text{ cm/s}^2$$

$$n = 34.8 \text{ g} \cdot \text{cm/s}^2 = \boxed{3.48 \times 10^{-4} \text{ N}}$$

ANSWERS TO EVEN NUMBERED PROBLEMS

2. No. Its density is only $2.70 \times 10^3\ \mathrm{kg/m^3}$

4. 1.92×10^4 N

6. (a) 1.01×10^7 Pa (b) 7.09×10^5 N outward

8. 225 N down

10. (a) 65.1 N (b) 275 N

12. (a) 10.3 m (b) 0

14. (a) 20.0 cm (b) 0.490 cm

16. (a) 1.57 Pa, 1.55×10^{-2} atm, 11.8 mm Hg
(b) The fluid level in the tap should rise.
(c) Blockage of flow of the cerebrospinal fluid.

18. $\dfrac{m}{(\rho_w - \rho_s)h}$

20. $\sim 10^4$

22. See the solution

24. 2.67×10^3 kg

26. See the solution. $T = \left(\dfrac{2}{r}\right)\sqrt{\dfrac{\pi M}{\rho g}}$

28. 12.8 kg/s

30. See the solution

32. (a) $h_0/2$ (b) h_0

34. (a) 1 atm + 15.0 MPa (b) 2.95 m/s (c) 4.34 kPa

36. $2.51 \times 10^{-3}\ \text{m}^3/\text{s}$

38. (a) 4.43 m/s (b) The siphon can be no higher than 10.3 m.

40. 12.6 m/s

42. $1.61 \times 10^{4}\ \text{m}^2$

44. 455 kPa

46. 0.604 m

48. 8.01 km; yes

50. 291 Hz

52. See the solution

54. (a) 18.3 mm (b) 14.3 mm (c) 8.56 mm

56. (a) 2.65 m/s (b) 2.31×10^{4} Pa