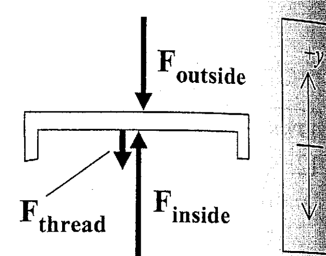
14. ***REASONING*** Since the weight is distributed uniformly, each tire exerts one-half of the weight of the rider and bike on the ground. According to the definition of pressure, Equation 11.3, the force that each tire exerts on the ground is equal to the pressure $P$ inside the tire times the area $A$ of contact between the tire and the ground. From this relation, the area of contact can be found.

***SOLUTION*** The area of contact that *each tire* makes with the ground is

$$A = \frac{F}{P} = \frac{\frac{1}{2}\left(W_{\text{person}} + W_{\text{bike}}\right)}{P} = \frac{\frac{1}{2}(625\text{ N} + 98\text{ N})}{7.60\times10^{5}\text{ Pa}} = \boxed{4.76\times10^{-4}\text{ m}^{2}} \quad (11.3)$$

15. ***REASONING*** The cap is in equilibrium, so the sum of all the forces acting on it must be zero. There are three forces in the vertical direction: the force $\mathbf{F}_{\text{inside}}$ due to the gas pressure inside the bottle, the force $\mathbf{F}_{\text{outside}}$ due to atmospheric pressure outside the bottle, and the force $\mathbf{F}_{\text{thread}}$ that the screw thread exerts on the cap. By setting the sum of these forces to zero, and using the relation $F = PA$, where $P$ is the pressure and $A$ is the area of the cap, we can determine the magnitude of the force that the screw threads exert on the cap.




***SOLUTION*** The drawing shows the free-body diagram of the cap and the three vertical forces that act on it. Since the cap is in equilibrium, the net force in the vertical direction must be zero.

$$\Sigma F_y = -F_{\text{thread}} + F_{\text{inside}} - F_{\text{outside}} = 0 \quad (4.9b)$$

Solving this equation for $F_{\text{thread}}$, and using the fact that force equals pressure times area, $F = PA$ (Equation 11.3), we have

$$F_{\text{thread}} = F_{\text{inside}} - F_{\text{outside}} = P_{\text{inside}}A - P_{\text{outside}}A$$

$$= \left(P_{\text{inside}} - P_{\text{outside}}\right)A = \left(1.80\times10^{5}\text{ Pa} - 1.01\times10^{5}\text{ Pa}\right)\left(4.10\times10^{-4}\text{ m}^{2}\right) = \boxed{32\text{ N}}$$

16. ***REASONING*** The power generated by the log splitter pump is the ratio of the work $W$ done on the piston to the elapsed time $t$:

$$\text{Power} = \frac{W}{t} \quad (6.10a)$$



The work done on the piston by the pump is equal to the magnitude $F$ of the force exerted on the piston by the hydraulic oil, multiplied by the distance $s$ through which the piston moves:

$$W = \left(F\cos 0^\circ\right)s = Fs \quad (6.1)$$

We have used $\theta = 0^\circ$ in Equation 6.1 because the piston moves in the same direction as the force acting on it. The magnitude $F$ of the force applied to the piston is given by

$$F = PA \quad (11.3)$$

where $A$ is the cross-sectional area of the piston and $P$ is the pressure of the hydraulic oil.

***SOLUTION*** The head of the piston is circular with a radius $r$, so its cross-sectional area is given by $A = \pi r^2$. Substituting Equation 11.3 into Equation 6.1, therefore, yields

$$W = PAs = P\pi r^2 s \quad (1)$$

Substituting Equation (1) into Equation 6.10a gives the power required to operate the pump:

$$\text{Power} = \frac{W}{t} = \frac{P\pi r^2 s}{t} = \frac{\left(2.0\times10^{7}\text{ Pa}\right)\pi\left(0.050\text{ m}\right)^2\left(0.60\text{ m}\right)}{25\text{ s}} = \boxed{3.8\times10^{3}\text{ W}}$$

17. ***REASONING*** The pressure $P$ due to the force $\mathbf{F}_{\text{SonF}}$ that the suitcase exerts on the elevator floor is given by $P = \frac{F_{\text{SonF}}}{A}$ (Equation 11.3), where $A$ is the area of the elevator floor beneath the suitcase (equal to the product of the length and width of that region). According to Newton's 3rd law, the magnitude $F_{\text{SonF}}$ of the downward force the suitcase exerts on the floor is equal to the magnitude $F_{\text{FonS}}$ of the upward force the floor exerts on the suitcase. We will use Newton's 2nd law, $\Sigma F = ma$ (Equation 4.1), to determine the magnitude $F_{\text{FonS}}$ of the upward force on the suitcase, which has a mass $m$ and an upward acceleration of magnitude $a = 1.5\text{ m/s}^2$, equal to that of the elevator.

***SOLUTION*** There are only two forces acting on the suitcase, the upward force $\mathbf{F}_{\text{FonS}}$ that the floor exerts on the suitcase, and the downward weight $W = mg$ (Equation 4.5) exerted by the earth, where $g$ is the magnitude of the acceleration due to gravity. Taking upwards as the positive direction, Newton's 2nd law yields

$$\Sigma F = F_{\text{FonS}} - mg = ma \quad (1)$$

Solving Equation (1) for $F_{\text{FonS}}$, and noting that by Newton's 3rd law, $F_{\text{FonS}} = F_{\text{SonF}}$, we obtain

24. ***REASONING AND SOLUTION*** The gauge pressure of the solution at the location of the vein is

$$P = \rho g h = (1030\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(0.610\ \text{m}) = 6.16 \times 10^3\ \text{Pa}$$

Now

$$1.013 \times 10^5\ \text{Pa} = 760\ \text{mm Hg} \quad \text{so} \quad 1\ \text{Pa} = 7.50 \times 10^{-3}\ \text{mm Hg}$$

Then

$$P = \left(6.16 \times 10^3\ \text{Pa}\right)\left(\frac{7.50 \times 10^{-3}\ \text{mm Hg}}{1\ \text{Pa}}\right) = \boxed{46.2\ \text{mm Hg}}$$

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25. ***REASONING*** Since the diver uses a snorkel, the pressure in her lungs is atmospheric pressure. If she is swimming at a depth $h$ below the surface, the pressure outside her lungs is atmospheric pressure plus that due to the water. The water pressure $P_2$ at the depth $h$ is related to the pressure $P_1$ at the surface by Equation 11.4, $P_2 = P_1 + \rho g h$, where $\rho$ is the density of the fluid, $g$ is the magnitude of the acceleration due to gravity, and $h$ is the depth. This relation can be used directly to find the depth.

***SOLUTION*** We are given that the maximum difference in pressure between the outside and inside of the lungs is one-twentieth of an atmosphere, or $P_2 - P_1 = \frac{1}{20}\left(1.01 \times 10^5\ \text{Pa}\right)$. Solving Equation 11.4 for the depth $h$ gives

$$h = \frac{P_2 - P_1}{\rho g} = \frac{\frac{1}{20}\left(1.01 \times 10^5\ \text{Pa}\right)}{\left(1025\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)} = \boxed{0.50\ \text{m}}$$

---

26. ***REASONING*** The pressure difference across the diver's eardrum is $P_{ext} - P_{int}$, where $P_{ext}$ is the external pressure and $P_{int}$ is the internal pressure. The diver's eardrum ruptures when $P_{ext} - P_{int} = 35\ \text{kPa}$. The exterior pressure $P_{ext}$ on the diver's eardrum increases with the depth $h$ of the dive according to $P_{ext} = P_{atm} + \rho g h$ (Equation 11.4), where $P_{atm}$ is the atmospheric pressure at the surface of the water, $\rho$ is the density of seawater, and $g$ is the magnitude of the acceleration due to gravity. Solving Equation 11.4 for the depth $h$ yields

$$h = \frac{P_{ext} - P_{atm}}{\rho g} \tag{1}$$

***SOLUTION*** When the diver is at the surface, the internal pressure is equalized with the external pressure: $P_{int} = P_{atm}$. If the diver descends slowly from the surface, and takes steps to equalize the exterior and interior pressures, there is no pressure difference across the eardrum, regardless of depth: $P_{ext} = P_{int}$. But if the diver sinks rapidly to a depth $h$ without equalizing the pressures, then the internal pressure is still atmospheric pressure. In this case, $P_{atm}$ in Equation (1) equals $P_{int}$, so the eardrum is at risk for rupture at the depth $h$ given by

$$h = \frac{35\ \text{kPa}}{\left(1025\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)} = \frac{35 \times 10^3\ \text{Pa}}{\left(1025\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)} = \boxed{3.5\ \text{m}}$$



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27. $\boxed{\text{SSM}}$ ***REASONING AND SOLUTION***

a. The pressure at the level of house A is given by Equation 11.4 as $P = P_{atm} + \rho g h$. Now the height $h$ consists of the 15.0 m and the diameter $d$ of the tank. We first calculate the radius of the tank, from which we can infer $d$. Since the tank is spherical, its full mass is given by $M = \rho V = \rho[(4/3)\pi r^3]$. Therefore,

$$r^3 = \frac{3M}{4\pi\rho} \quad \text{or} \quad r = \left(\frac{3M}{4\pi\rho}\right)^{1/3} = \left[\frac{3(5.25 \times 10^5\ \text{kg})}{4\pi(1.000 \times 10^3\ \text{kg/m}^3)}\right]^{1/3} = 5.00\ \text{m}$$

Therefore, the diameter of the tank is 10.0 m, and the height $h$ is given by

$$h = 10.0\ \text{m} + 15.0\ \text{m} = 25.0\ \text{m}$$

According to Equation 11.4, the gauge pressure in house A is, therefore,

$$P - P_{atm} = \rho g h = (1.000 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(25.0\ \text{m}) = \boxed{2.45 \times 10^5\ \text{Pa}}$$

b. The pressure at house B is $P = P_{atm} + \rho g h$, where

$$h = 15.0\ \text{m} + 10.0\ \text{m} - 7.30\ \text{m} = 17.7\ \text{m}$$

According to Equation 11.4, the gauge pressure in house B is

$$P - P_{atm} = \rho g h = (1.000 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(17.7\ \text{m}) = \boxed{1.73 \times 10^5\ \text{Pa}}$$

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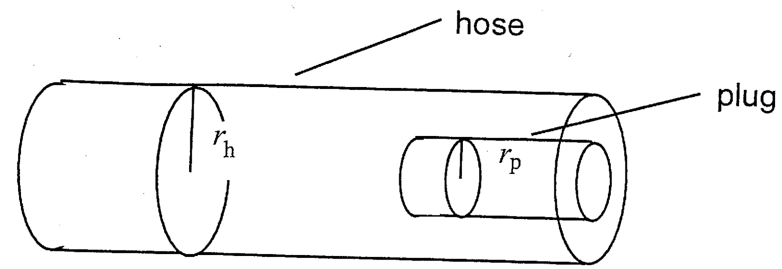
28. ***REASONING*** In each case the pressure at point A in Figure 11.11 is atmospheric pressure and the pressure in the tube above the top of the liquid column is $P$. In Equation 11.4 ($P_2 = P_1 + \rho g h$), this means that $P_2 = P_{atmosphere}$ and $P_1 = P$. With this identification of the pressures and a value of 13 600 kg/m$^3$ for the density of mercury (see Table 11.1), Equation 11.4 provides a solution to the problem.

59. ***REASONING AND SOLUTION*** Let $r_h$ represent the inside radius of the hose, and $r_p$ the radius of the plug, as suggested by the figure below.




Then, from Equation 11.9, $A_1 v_1 = A_2 v_2$, we have $\pi r_h^2 v_1 = (\pi r_h^2 - \pi r_p^2) v_2$, or

$$\frac{v_1}{v_2} = \frac{\left(r_h^2 - r_p^2\right)}{r_h^2} = 1 - \left(\frac{r_p}{r_h}\right)^2 \quad \text{or} \quad \frac{r_p}{r_h} = \sqrt{1 - \frac{v_1}{v_2}}$$

According to the problem statement, $v_2 = 3v_1$, or

$$\frac{r_p}{r_h} = \sqrt{1 - \frac{v_1}{3v_1}} = \sqrt{\frac{2}{3}} = \boxed{0.816}$$

60. ***REASONING*** The number N of capillaries can be obtained by dividing the total cross-sectional area $A_{cap}$ of all the capillaries by the cross-sectional area $a_{cap}$ of a single capillary. We know the radius $r_{cap}$ of a single capillary, so $a_{cap}$ can be calculated as $a_{cap} = \pi r_{cap}^2$. To find $A_{cap}$, we will use the equation of continuity.

***SOLUTION*** The number N of capillaries is

$$N = \frac{A_{cap}}{a_{cap}} = \frac{A_{cap}}{\pi r_{cap}^2} \tag{1}$$

where the cross-sectional area $a_{cap}$ of a single capillary has been replaced by $a_{cap} = \pi r_{cap}^2$. To obtain the total cross-sectional area $A_{cap}$ of all the capillaries, we use the equation of continuity for an incompressible fluid (see Equation 11.9). For present purposes, this equation is

$$A_{aorta} v_{aorta} = A_{cap} v_{cap} \quad \text{or} \quad A_{cap} = \frac{A_{aorta} v_{aorta}}{v_{cap}} \tag{2}$$



The cross-sectional area of the aorta is $A_{aorta} = \pi r_{aorta}^2$, and with this substitution, Equation (2) becomes

$$A_{cap} = \frac{A_{aorta} v_{aorta}}{v_{cap}} = \frac{\pi r_{aorta}^2 v_{aorta}}{v_{cap}}$$

Substituting this result into Equation (1), we find that

$$N = \frac{A_{cap}}{\pi r_{cap}^2} = \frac{\left(\frac{\pi r_{aorta}^2}{v_{cap}}\right) v_{aorta}}{\pi r_{cap}^2} = \frac{r_{aorta}^2 v_{aorta}}{r_{cap}^2 v_{cap}}$$

$$= \frac{(1.1\text{ cm})^2 (40\text{ cm/s})}{\left(6\times 10^{-4}\text{ cm}\right)^2 (0.07\text{ cm/s})} = \boxed{2\times 10^9}$$

61. SSM ***REASONING AND SOLUTION***

a. Using Equation 11.12, the form of Bernoulli's equation with $y_1 = y_2$, we have

$$P_1 - P_2 = \tfrac{1}{2}\rho\left(v_2^2 - v_1^2\right) = \frac{1.29\text{ kg/m}^3}{2}\left[(15\text{ m/s})^2 - (0\text{ m/s})^2\right] = \boxed{150\text{ Pa}}$$

b. The pressure inside the roof is greater than the pressure on the outside. Therefore, there is a net outward force on the roof. If the wind speed is sufficiently high, some roofs are "blown outward."

62. ***REASONING*** We apply Bernoulli's equation as follows:

$$\underbrace{P_S + \tfrac{1}{2}\rho v_S^2 + \rho g y_S}_{\text{At surface of vaccine in reservoir}} = \underbrace{P_O + \tfrac{1}{2}\rho v_O^2 + \rho g y_O}_{\text{At opening}}$$

***SOLUTION*** The vaccine's surface in the reservoir is stationary during the inoculation, so that $v_S = 0$ m/s. The vertical height between the vaccine's surface in reservoir and the opening can be ignored, so $y_S = y_O$. With these simplifications Bernoulli's equation becomes

$$P_S = P_O + \tfrac{1}{2}\rho v_O^2$$

Solving for the speed at the opening gives

66. ***REASONING*** The volume of water per second leaking into the hold is the volume flow rate $Q$. The volume flow rate is the product of the effective area $A$ of the hole and the speed $v_1$ of the water entering the hold, $Q = Av_1$ (Equation 11.10). We can find the speed $v_1$ with the aid of Bernoulli's equation.

***SOLUTION*** According to Bernoulli's equation, which relates the pressure $P$, water speed $v$, and elevation $y$ of two points in the water:

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2 \qquad (11.11)$$

In this equation, the subscript "1" refers to the point below the surface where the water enters the hold, and the subscript "2" refers to a point on the surface of the lake. Since the amount of water in the lake is large, the water level at the surface drops very, very slowly as water enters the hold of the ship. Thus, to a very good approximation, the speed of the water at the surface is zero, so $v_2 = 0$ m/s. Setting $P_1 = P_2$ (since the empty hold is open to the atmosphere) and $v_2 = 0$ m/s, and then solving for $v_1$, we obtain $v_1 = \sqrt{2g(y_2 - y_1)}$.

Substituting $v_1 = \sqrt{2g(y_2 - y_1)}$ into Equation 11.10, we find that the volume flow rate $Q$ of the water entering the hold is

$$Q = Av_1 = A\sqrt{2g(y_2 - y_1)} = (8.0\times10^{-3}\,\text{m}^2)\sqrt{2(9.80\,\text{m/s}^2)(2.0\,\text{m})} = \boxed{5.0\times10^{-2}\,\text{m}^3/\text{s}}$$

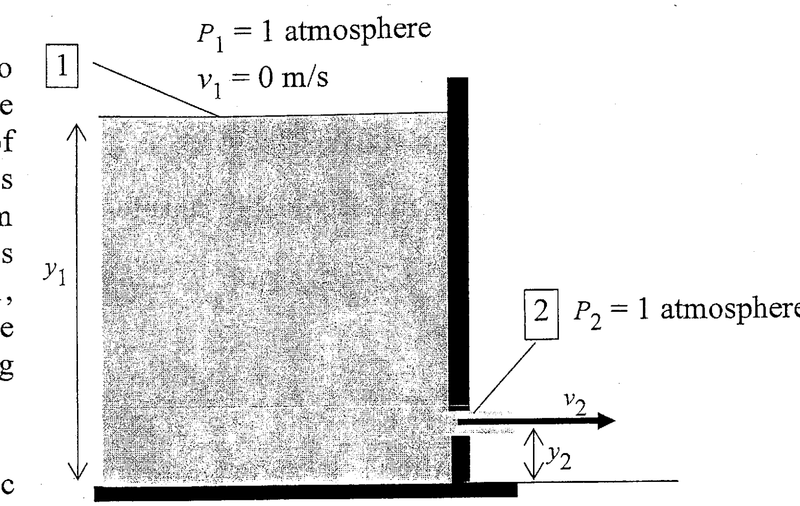
67. ***REASONING*** The pressure $P$, the fluid speed $v$, and the elevation $y$ at any two points in an ideal fluid of density $\rho$ are related by Bernoulli's equation: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$ (Equation 11.11), where 1 and 2 denote, respectively, the first and second floors. With the given data and a density of $\rho = 1.00 \times 10^3$ kg/m$^3$ for water (see Table 11.1), we can solve Bernoulli's equation for the desired pressure $P_2$.

***SOLUTION***
Solving Bernoulli's equation for $P_2$ and taking the elevation at the first floor to be $y_1 = 0$ m, we have

$$P_2 = P_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right) + \rho g\left(y_1 - y_2\right)$$
$$= 3.4\times10^5\ \text{Pa} + \tfrac{1}{2}\left(1.00\times10^3\ \text{kg/m}^3\right)\left[(2.1\ \text{m/s})^2 - (3.7\ \text{m/s})^2\right]$$
$$+\left(1.00\times10^3\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)\left(0\ \text{m} - 4.0\ \text{m}\right) = \boxed{3.0\times10^5\ \text{Pa}}$$



68. ***REASONING***
a. The drawing shows two points, labeled 1 and 2, in the fluid. Point 1 is at the top of the water, and point 2 is where it flows out of the dam at the bottom. Bernoulli's equation, Equation 11.11, can be used to determine the speed $v_2$ of the water exiting the dam.




b. The number of cubic meters per second of water that leaves the dam is the volume flow rate $Q$. According to Equation 11.10, the volume flow rate is the product of the cross-sectional area $A_2$ of the crack and the speed $v_2$ of the water; $Q = A_2 v_2$.

***SOLUTION***
a. According to Bernoulli's equation, as given in Equation 11.11, we have

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

Setting $P_1 = P_2$, $v_1 = 0$ m/s, and solving for $v_2$, we obtain

$$v_2 = \sqrt{2g(y_1 - y_2)} = \sqrt{2(9.80\ \text{m/s}^2)(15.0\ \text{m})} = \boxed{17.1\ \text{m/s}}$$

b. The volume flow rate of the water leaving the dam is

$$Q = A_2 v_2 = \left(1.30\times10^{-3}\,\text{m}^2\right)(17.1\ \text{m/s}) = \boxed{2.22\times10^{-2}\ \text{m}^3/\text{s}} \qquad (11.10)$$

69. $\boxed{\text{SSM}}$ ***REASONING*** Since the pressure difference is known, Bernoulli's equation can be used to find the speed $v_2$ of the gas in the pipe. Bernoulli's equation also contains the unknown speed $v_1$ of the gas in the Venturi meter; therefore, we must first express $v_1$ in terms of $v_2$. This can be done by using Equation 11.9, the equation of continuity.

***SOLUTION***

a. From the equation of continuity (Equation 11.9) it follows that $v_1 = (A_2/A_1)v_2$. Therefore,

$$v_1 = \frac{0.0700\ \text{m}^2}{0.0500\ \text{m}^2} v_2 = (1.40)v_2$$

Substituting this expression into Bernoulli's equation (Equation 11.12), we have

$$P_1 + \tfrac{1}{2}\rho(1.40\ v_2)^2 = P_2 + \tfrac{1}{2}\rho v_2^2$$

Solving for $v_2$, we obtain

$$v_2 = \sqrt{\frac{2(P_2 - P_1)}{\rho\left[(1.40)^2 - 1\right]}} = \sqrt{\frac{2(120\ \text{Pa})}{(1.30\ \text{kg/m}^3)\left[(1.40)^2 - 1\right]}} = \boxed{14\ \text{m/s}}$$

b. According to Equation 11.10, the volume flow rate is

$$Q = A_2 v_2 = (0.0700\ \text{m}^2)(14\ \text{m/s}) = \boxed{0.98\ \text{m}^3/\text{s}}$$

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70. ***REASONING*** The gauge pressure in the reservoir is the pressure difference $P_2 - P_1$ between the reservoir ($P_2$) and the atmosphere ($P_1$). The muzzle is open to the atmosphere, so the pressure there is atmospheric pressure. Because we are ignoring the height difference between the reservoir and the muzzle, this is an example of fluid flow in a horizontal pipe, for which Bernoulli's equation is

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2 \qquad (11.12)$$

Solving Equation 11.12 for the gauge pressure $P_2 - P_1$ yields

$$P_2 - P_1 = \tfrac{1}{2}\rho v_1^2 - \tfrac{1}{2}\rho v_2^2 = \tfrac{1}{2}\rho v_1^2 \qquad (1)$$

where we have used the fact that the speed $v_2$ of the water in the reservoir is zero. We will determine the speed $v_1$ of the water stream at the muzzle by considering its subsequent projectile motion. The horizontal displacement of the water stream after leaving the muzzle is given by $x = v_{0x}t + \frac{1}{2}a_x t^2$ (Equation 3.5a). With air resistance neglected, the water stream undergoes no horizontal acceleration ($a_x = 0$ m/s$^2$). The horizontal component $v_{0x}$ of the initial velocity of the water stream is identical with the velocity $v_1$ in Equation (1), so Equation 3.5a becomes



$$x = v_1 t + \tfrac{1}{2}\left(0\ \text{m/s}^2\right)t^2 \quad \text{or} \quad v_1 = \frac{x}{t} \qquad (2)$$

The vertical displacement $y$ of the water stream is given by $y = v_{0y}t + \frac{1}{2}a_y t^2$ (Equation 3.5b), where $a_y$ = - 9.8 m/s$^2$ is the acceleration due to gravity, with upward taken as the positive direction. The velocity of the water at the instant it leaves the muzzle is horizontal, so the vertical component of its velocity is zero. This means that we have $v_{0y}$ = 0 m/s in Equation 3.5b. Solving Equation 3.5b for the elapsed time $t$, we obtain

$$y = (0\ \text{m/s})t + \tfrac{1}{2}a_y t^2 \quad \text{or} \quad t = \sqrt{\frac{2y}{a_y}} \qquad (3)$$

***SOLUTION*** Substituting Equation (3) into Equation (2) gives

$$v_1 = \frac{x}{\sqrt{\frac{2y}{a_y}}} = x\sqrt{\frac{a_y}{2y}} \qquad (4)$$

Substituting Equation (4) for $v_1$ into Equation (1), we obtain the gauge pressure $P_2 - P_1$:

$$P_2 - P_1 = \tfrac{1}{2}\rho\left(x\sqrt{\frac{a_y}{2y}}\right)^2 = \tfrac{1}{2}\rho x^2\left(\frac{a_y}{2y}\right) = \frac{\rho x^2 a_y}{4y}$$

$$= \frac{\left(1.000\times10^3\ \text{kg/m}^3\right)(7.3\ \text{m})^2\left(-9.80\ \text{m/s}^2\right)}{4(-0.75\ \text{m})} = \boxed{1.7\times10^5\ \text{Pa}}$$

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71. ***REASONING AND SOLUTION***

a. Taking the nozzle as position 1 and the top of the tank as position 2 we have, using Bernoulli's equation, $P_1 + (1/2)\rho v_1^2 = P_2 + \rho gh$, we can solve for $v_1$ so that

$$v_1^2 = 2[(P_2 - P_1)/\rho + gh]$$

$$v_1 = \sqrt{2[(5.00\times10^5\ \text{Pa})/(1.00\times10^3\ \text{kg/m}^3) + (9.80\ \text{m/s}^2)(4.00\ \text{m})]} = \boxed{32.8\ \text{m/s}}$$

b. To find the height of the water use $(1/2)\rho v_1^{\,2} = \rho g h$ so that

$$h = (1/2)v_1^{\,2}/g = (1/2)(32.8\text{ m/s})^2/(9.80\text{ m/s}^2) = \boxed{54.9\text{ m}}$$

72. ***REASONING*** In level flight the lift force must balance the plane's weight $W$, so its magnitude is also $W$. The lift force arises because the pressure $P_B$ beneath the wings is greater than the pressure $P_T$ on top of the wings. The lift force, then, is the pressure difference times the effective wing surface area $A$, so that $W = (P_B - P_T)A$. The area is given, and we can determine the pressure difference by using Bernoulli's equation.

***SOLUTION*** According to Bernoulli's equation, we have

$$P_B + \tfrac{1}{2}\rho v_B^2 + \rho g y_B = P_T + \tfrac{1}{2}\rho v_T^2 + \rho g y_T$$

Since the flight is level, the height is constant and $y_B = y_T$, where we assume that the wing thickness may be ignored. Then, Bernoulli's equation simplifies and may be rearranged as follows:

$$P_B + \tfrac{1}{2}\rho v_B^2 = P_T + \tfrac{1}{2}\rho v_T^2 \quad \text{or} \quad P_B - P_T = \tfrac{1}{2}\rho v_T^2 - \tfrac{1}{2}\rho v_B^2$$

Recognizing that $W = (P_B - P_T)A$, we can substitute for the pressure difference from Bernoulli's equation to show that

$$W = (P_B - P_T)A = \tfrac{1}{2}\rho\left(v_T^2 - v_B^2\right)A$$

$$= \tfrac{1}{2}\left(1.29\text{ kg/m}^3\right)\left[(62.0\text{ m/s})^2 - (54.0\text{ m/s})^2\right]\left(16\text{ m}^2\right) = \boxed{9600\text{ N}}$$

We have used a value of 1.29 kg/m$^3$ from Table 11.1 for the density of air. This is an approximation, since the density of air decreases with increasing altitude above sea level.

73. ***REASONING*** The top and bottom surfaces of the roof are at the same height, so we can use Bernoulli's equation in the form of Equation 11.12, $P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2$, to determine the wind speed. We take point 1 to be inside the roof and point 2 to be outside the roof. Since the air inside the roof is not moving, $v_1 = 0$ m/s. The net outward force $\Sigma F$ acting on the roof is the difference in pressure $P_1 - P_2$ times the area $A$ of the roof, so $\Sigma F = (P_1 - P_2)A$.



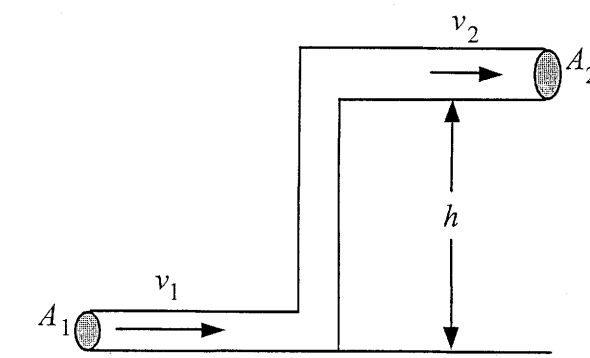
***SOLUTION*** Setting $v_1 = 0$ m/s in Bernoulli's equation and solving it for the speed $v_2$ of the wind, we obtain

$$v_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

Since the pressure difference is equal to the net outward force divided by the area of the roof, $(P_1 - P_2) = \Sigma F/A$, the speed of the wind is

$$v_2 = \sqrt{\frac{2(\Sigma F)}{\rho A}} = \sqrt{\frac{2(22\ 000\text{ N})}{(1.29\text{ kg/m}^3)(5.0\text{ m}\times 6.3\text{ m})}} = \boxed{33\text{ m/s}}$$

74. ***REASONING AND SOLUTION*** As seen in the figure, the lower pipe is at the level of zero potential energy.




If the flow rate is uniform in both pipes, we have $(1/2)\rho v_1^{\,2} = (1/2)\rho v_2^{\,2} + \rho g h$ (since $P_1 = P_2$) and $A_1 v_1 = A_2 v_2$. We can solve for $v_1$, i.e., $v_1 = v_2(A_2/A_1)$, and plug into the previous expression to find $v_2$, so that

$$v_2 = \sqrt{\frac{2gh}{\left(\frac{A_2}{A_1}\right)^2 - 1}} = \sqrt{\frac{2\left(9.80\text{ m/s}^2\right)(10.0\text{ m})}{\left[\frac{\pi(0.0400\text{ m})^2}{\pi(0.0200\text{ m})^2}\right]^2 - 1}} = 3.61\text{ m/s}$$

The volume flow rate is then given by

$$Q = A_2 v_2 = \pi r_2^{\,2} v_2 = \pi(0.0400\text{ m})^2(3.61\text{ m/s}) = \boxed{1.81\times 10^{-2}\text{ m}^3/\text{s}}$$

Both liquids are incompressible and immiscible so

$$h_w = 1.00 \text{ m} \text{ and } h_{mL} + h_{mR} = 1.00 \text{ m}$$

Using these in (1) and solving for $h_{mL}$ gives, $h_{mL} = (1/2)(1.00 - \rho_w/\rho_m) = 0.46$ m.

So the fluid level in the left container is 1.00 m + 0.46 m = $\boxed{1.46 \text{ m}}$ from the bottom.

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99. SSM WWW ***REASONING AND SOLUTION*** The pressure at the bottom of the container is

$$P = P_{atm} + \rho_w g h_w + \rho_m g h_m$$

We want $P = 2P_{atm}$, and we know $h = h_w + h_m = 1.00$ m. Using the above and rearranging gives

$$h_m = \frac{P_{atm} - \rho_w g h}{(\rho_m - \rho_w) g} = \frac{1.01\times10^5 \text{ Pa} - (1.00\times10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(1.00 \text{ m})}{(13.6\times10^3 \text{ kg/m}^3 - 1.00\times10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = \boxed{0.74 \text{ m}}$$

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100. ***REASONING AND SOLUTION*** We refer to Table 11.1 for values of $\rho_{soda} = \rho_{water} = 1.000 \times 10^3$ kg/m$^3$ and $\rho_{Al} = 2700$ kg/m$^3$ for the density of aluminum. The mass of aluminum required to make the can is

$$m_{Al} = m_{total} - m_{soda}$$

where the mass of the soda is

$$m_{soda} = \rho_{soda} V_{soda} = (1.000 \times 10^3 \text{ kg/m}^3)(3.54 \times 10^{-4} \text{ m}^3) = 0.354 \text{ kg}$$

Therefore, the mass of the aluminum used to make the can is

$$m_{Al} = 0.416 \text{ kg} - 0.354 \text{ kg} = 0.062 \text{ kg}$$

Using the definition of density, $\rho = m/V$, we have

$$V_{Al} = \frac{m_{Al}}{\rho_{Al}} = \frac{0.062 \text{ kg}}{2700 \text{ kg/m}^3} = \boxed{2.3\times10^{-5} \text{ m}^3}$$

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101. ***REASONING*** The number of gallons per minute of water that the fountain uses is the volume flow rate $Q$ of the water. According to Equation 11.10, the volume flow rate is $Q = Av$, where $A$ is the cross-sectional area of the pipe and $v$ is the speed at which the water leaves the pipe. The area is given. To find a value for the speed, we will use Bernoulli's equation. This equation states that the pressure $P$, the fluid speed $v$, and the elevation $y$ at any two points (1 and 2) in an ideal fluid of density $\rho$ are related according to $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$ (Equation 11.11). Point 1 is where the water leaves the pipe, so we are seeking $v_1$. We must now select point 2. Note that the problem specifies the maximum height to which the water rises. The maximum height occurs when the water comes to a momentary halt at the top of its path in the air. Therefore, we choose this point as point 2, so that we can take advantage of the fact that $v_2 = 0$ m/s.

***SOLUTION*** We know that $P_1 = P_2 = P_{atmospheric}$ and $v_2 = 0$ m/s. Substituting this information into Bernoulli's equation, we obtain

$$P_{atmospheric} + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_{atmospheric} + \frac{1}{2}\rho(0 \text{ m/s})^2 + \rho g y_2$$

Solving for $v_1$ gives $v_1 = \sqrt{2g(y_2 - y_1)}$, which we now substitute for the speed $v$ in the expression $Q = Av$ for the volume flow rate:

$$Q = Av_1 = A\sqrt{2g(y_2 - y_1)}$$

$$= (5.00\times10^{-4} \text{ m}^2)\sqrt{2(9.80 \text{ m/s}^2)(5.00 \text{ m} - 0 \text{ m})} = 4.95\times10^{-3} \text{ m}^3/\text{s}$$

To convert this result to gal / min, we use the facts that 1 gal = $3.79 \times 10^{-3}$ m$^3$ and 1 min = 60 s:

$$Q = \left(4.95\times10^{-3} \frac{\cancel{\text{m}^3}}{\cancel{\text{s}}}\right)\left(\frac{1 \text{ gal}}{3.79\times10^{-3} \cancel{\text{m}^3}}\right)\left(\frac{60 \cancel{\text{s}}}{1 \text{ min}}\right) = \boxed{78.4 \text{ gal / min}}$$

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102. ***REASONING AND SOLUTION*** The upward buoyant force must equal the weight of the shell if it is floating, $\rho_w g V = W$. The submerged volume of the shell is $V = (4/3)\pi R_2^3$, where $R_2$ is its outer radius. Now $R_2^3 = (3/4)m/(\rho_w \pi)$ gives

$$R_2 = \sqrt[3]{\frac{3m}{4\pi\rho_w}} = \sqrt[3]{\frac{3(1.00 \text{ kg})}{4\pi(1.00\times10^3 \text{ kg/m}^3)}} = \boxed{6.20\times10^{-2} \text{m}}$$