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

***15.4** Let F_g be its weight. Then each tire supports $F_g/4$, so $P = \frac{F}{A} = \frac{F_g}{4A}$

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

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

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

(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

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

15.12 The pressure on the bottom due to the water is

$$P_b = \rho g z = 1.96 \times 10^4\ \text{Pa}$$

So, $F_b = P_b A = \boxed{5.88 \times 10^6\ \text{N}}$

On each end,

$$F = \bar{P}A = (9.80 \times 10^3\ \text{Pa})(20.0\ \text{m}^2) = \boxed{196\ \text{kN}}$$

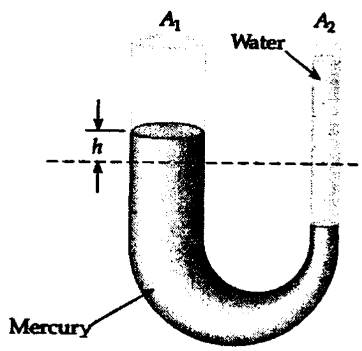
On the side

$$F = \bar{P}A = (9.80 \times 10^3\ \text{Pa})(60.0\ \text{m}^2) = \boxed{588\ \text{kN}}$$

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

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

(b) The sketch 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,



(b)

$$A_2h_2 = A_1h$$

or $h_2 = \dfrac{A_1}{A_2}h$ (1)

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

$$P = P_0 + \rho_{\text{water}} g h_w$$

The pressure at this same level in the left tube is given by

$$P = P_0 + \rho_{\text{Hg}} g(h + h_2) = P_0 + \rho_{\text{water}} g h_w$$

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

*15.26 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

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

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

$$F_{\text{up}} = (1.29 - 0.179)\frac{\text{kg}}{\text{m}^3}\frac{4}{3}\pi(0.125\text{ m})^3(9.80\text{ m/s}^2) - 5.00\times 10^{-3}\text{ kg}(9.80\text{ m/s}^2)$$

$$F_{\text{up}} = 0.0401\text{ N}$$

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

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

you need this many balloons:

$$\frac{686\text{ N}}{0.0401\text{ N}} = 17\,000 \sim \boxed{10^4}$$

*15.33 Volume flow rate $= A_1v_1 = A_2v_2$

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

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

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

15.35 Assuming the top is open to the atmosphere, then

$$P_1 = P_0$$

Note $P_2 = P_0$

Flow rate $= 2.50 \times 10^{-3}\text{ m}^3/\text{min} = 4.17 \times 10^{-5}\text{ m}^3/\text{s}$

(a) $A_1 >> A_2$ so $v_1 << v_2$

Assuming $v_1 \approx 0$,

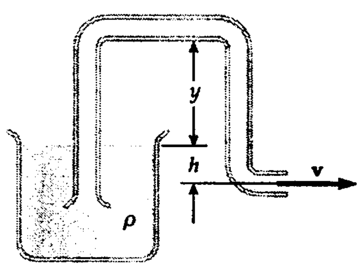
$$P_1 + \frac{\rho v_1^2}{2} + \rho g y_1 = P_2 + \frac{\rho v_2^2}{2} + \rho g y_2$$

$$v_2 = (2gy_1)^{1/2} = [2(9.80)(16.0)]^{1/2} = \boxed{17.7\text{ m/s}}$$

(b) Flow rate $= A_2 v_2 = \left(\dfrac{\pi d^2}{4}\right)(17.7) = 4.17 \times 10^{-5}\text{ m}^3/\text{s}$

$$d = \boxed{1.73 \times 10^{-3}\text{ m}} = 1.73\text{ mm}$$

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



$v_3 = \sqrt{2gh}$

If $h = 1.00$ 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 $P \geq 0$,

$$y \leq \frac{P_0}{\rho g} = \frac{(1.013 \times 10^5\text{ Pa})}{(10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)} = \boxed{10.3\text{ m}}$$

***15.44** In the reservoir, the gauge pressure is

$$\Delta P = \frac{2.00\text{ N}}{2.50 \times 10^{-5}\text{ m}^2} = 8.00 \times 10^4\text{ Pa}$$

From the equation of continuity:

$$A_1 v_1 = A_2 v_2$$

$$(2.50 \times 10^{-5}\text{ m}^2) v_1 = (1.00 \times 10^{-8}\text{ m}^2) v_2$$

$$v_1 = (4.00 \times 10^{-4}) v_2$$

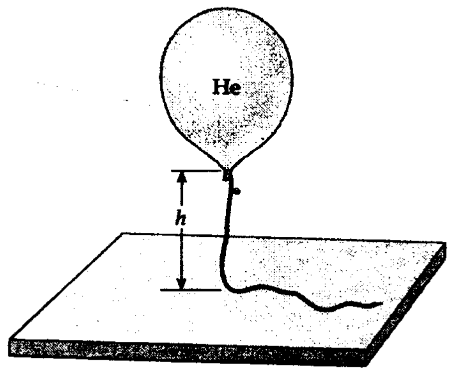
Thus, v_1^2 is negligible in comparison to v_2^2. Then, from Bernoulli's equation:

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

$$8.00 \times 10^4\text{ Pa} + 0 + 0 = 0 + \frac{1}{2}(1000\text{ kg/m}^3) v_2^2$$

$$v_2 = \sqrt{\frac{2(8.00 \times 10^4\text{ Pa})}{1000\text{ kg/m}^3}} = \boxed{12.6\text{ m/s}}$$

15.49 When the balloon comes into equilibrium, we must have



$$\Sigma F_y = B - F_{g,\text{ balloon}} - F_{g,\text{He}} - F_{g,\text{string}} = 0$$

$F_{g,\text{ string}}$ is the weight of the string above the ground, and B is the buoyant force. Now

$$F_{g,\text{ balloon}} = m_{\text{balloon}}\, g$$

$$F_{g,\text{ He}} = \rho_{\text{He}} V g$$

$$B = \rho_{\text{air}} V g$$

and $F_{g,\text{ string}} = m_{\text{string}} \dfrac{h}{L} g$

$$\rho_{\text{air}} V g - m_{\text{balloon}}\, g - \rho_{\text{He}} V g - m_{\text{string}} \frac{h}{L} g = 0$$

or $$h = \frac{(\rho_{\text{air}} - \rho_{\text{He}}) V - m_{\text{balloon}}}{m_{\text{string}}} L$$

giving,

$$h = \frac{(1.29 - 0.179)\text{ kg/m}^3 \left(\frac{4\pi(0.400\text{ m})^3}{3}\right) - 0.250\text{ kg}}{0.0500\text{ kg}}(2.00\text{ m}) = \boxed{1.91\text{ m}}$$

15.39 $Mg = (P_1 - P_2)A$ for a balanced condition

$$\frac{(16000)(9.80)}{A} = 7.00 \times 10^4 - P_2$$

where $A = 80.0\text{ m}^2$,

$$\therefore P_2 = 7.00 \times 10^4 - 0.196 \times 10^4 = \boxed{6.80 \times 10^4\text{ Pa}}$$