15.37. Solve: (a) We can measure the atmosphere's pressure by measuring the height of the liquid column in a barometer, because $p_{\text{atmos}} = \rho g h$. In the case of the water barometer, the height of the column at a pressure of 1 atm is

$$h = \frac{p_{\text{atmos}}}{\rho_{\text{water}} g} = \frac{1.013 \times 10^5 \text{ Pa}}{(1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)} = 10.337 \text{ m}$$

Because the pressure of the atmosphere can vary by 5 percent, the height of the barometer must be at least be 1.05 greater than this amount. That is, $h_{\text{min}} = 10.85$ m.
(b) Using the conversion rate1 atm = 29.92 inches of Hg, we have

$$29.55 \text{ inches of Hg} = \frac{29.55}{29.92} \times 1 \text{ atm} = 0.9876 \text{ atm}$$

The height of the water in your barometer will be

$$h = \frac{p_{\text{atmos}}}{\rho_{\text{water}} g} = \frac{0.9876 \times 1.013 \times 10^5 \text{ Pa}}{(1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)} = 10.21 \text{ m}$$

15.38. Model: Oil is incompressible and has a density 900 kg/m^3.
Visualize: Please refer to Figure P15.38.
Solve: **(a)** The pressure at point A, which is 0.50 m below the open oil surface, is

$$p_A = p_0 + \rho_{oil} g(1.00\text{ m} - 0.50\text{ m}) = 101{,}300\text{ Pa} + (900\text{ kg/m}^3)(9.8\text{ m/s}^2)(0.50\text{ m}) = 105{,}700\text{ Pa}$$

(b) The pressure difference between A and B is

$$p_B - p_A = (p_0 + \rho g d_B) - (p_0 + \rho g d_A) = \rho g(d_B - d_A) = (900\text{ kg/m}^3)(9.8\text{ m/s}^2)(0.50\text{ m}) = 4410\text{ Pa}$$

Pressure depends only on depth, and C is the same depth as B. Thus $p_C - p_A = 4410$ Pa also, even though C isn’t directly under A.

15.39. Model: Assume that oil is incompressible and its density is 900 kg/m^3.

Visualize: Please refer to Figure P15.39.

Solve: **(a)** The hydraulic lift is in equilibrium and the pistons on the left and the right are at the same level. Equation 15.11, therefore, simplifies to

$$\frac{F_{\text{left piston}}}{A_{\text{left piston}}} = \frac{F_{\text{right piston}}}{A_{\text{right piston}}} \Rightarrow \frac{w_{\text{student}}}{\pi\left(r_{\text{student}}\right)^2} = \frac{w_{\text{elephant}}}{\pi\left(r_{\text{elephant}}\right)^2}$$

$$\Rightarrow r_{\text{student}} = \sqrt{\left(\frac{w_{\text{student}}}{w_{\text{elephant}}}\right)}\left(r_{\text{elephant}}\right) = \sqrt{\frac{(70\text{ kg})g}{(1200\text{ kg})g}}(1.0\text{ m}) = 0.2415\text{ m}$$

The diameter of the piston the student is standing on is therefore $2 \times 0.2415\text{ m} = 0.483\text{ m}$.

(b) From Equation 15.13, we see that an additional force ΔF is required to increase the elephant's elevation through a distance d_2. That is,

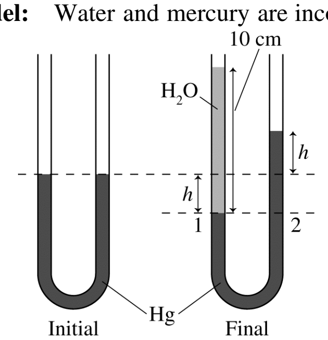
$$\Delta F = \rho g\left(A_{\text{left piston}} + A_{\text{right piston}}\right)d_2$$

$$\Rightarrow (70\text{ kg})\left(9.8\text{ m/s}^2\right) = \left(900\text{ kg/m}^3\right)\left(9.8\text{ m/s}^2\right)\pi\left[(0.2415\text{ m})^2 + (1.0\text{ m})^2\right]d_2$$

$$\Rightarrow d_2 = 0.0234\text{ m} = 2.34\text{ cm}$$

15.41. Model: Water and mercury are incompressible and immiscible liquids.

Visualize:



The water in the left arm floats on top of the mercury and presses the mercury down from its initial level. Because points 1 and 2 are level with each other *and* the fluid is in static equilibrium, the pressure at these two points must be equal. If the pressures were not equal, the pressure difference would cause the fluid to flow, violating the assumption of static equilibrium.

Solve: The pressure at point 1 is due to water of depth $d_w = 10$ cm:

$$p_1 = p_{atmos} + \rho_w g d_w$$

Because mercury is incompressible, the mercury in the left arm goes down a distance h while the mercury in the right arm goes up a distance h. Thus, the pressure at point 2 is due to mercury of depth $d_{Hg} = 2h$:

$$p_2 = p_{atmos} + \rho_{Hg} g d_{Hg} = p_{atmos} + 2\rho_{Hg} g h$$

Equating p_1 and p_2 gives

$$p_{atmos} + \rho_w g d_w = p_{atmos} + 2\rho_{Hg} g h \Rightarrow h = \frac{1}{2}\frac{\rho_w}{\rho_{Hg}} d_w = \frac{1}{2}\frac{1000\ \text{kg/m}^3}{13{,}600\ \text{kg/m}^3} 10\ \text{cm} = 3.7\ \text{mm}$$

The mercury in the right arm rises 3.7 mm above its initial level.

15.61. Model: Treat the water as an ideal fluid obeying Bernoulli's equation. A streamline begins in the bigger size pipe and ends at the exit of the narrower pipe.

Visualize: Please see Figure P15.61. Let point 1 be beneath the standing column and point 2 be where the water exits the pipe.

Solve: **(a)** The pressure of the water as it exits into the air is $p_2 = p_{atmos}$.

(b) Bernoulli's equation, Equation 15.28, relates the pressure, water speed, and heights at points 1 and 2:

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

From the continuity equation,

$$v_1 A_1 = v_2 A_2 = (4 \text{ m/s})\left(5\times 10^{-4} \text{ m}^2\right) = v_1\left(10\times 10^{-4} \text{ m}^2\right) = 20\times 10^{-4} \text{ m}^3/\text{s} \Rightarrow v_1 = 2 \text{ m/s}$$

Substituting into Bernoulli's equation,

$$p_1 - p_2 = p_1 - p_{atmos} = \tfrac{1}{2}\left(1000 \text{ kg/m}^3\right)\left[(4 \text{ m/s})^2 - (2 \text{ m/s})^2\right] + \left(1000 \text{ kg/m}^3\right)(9.8 \text{ m/s})(4.0 \text{ m})$$

$$= 6000 \text{ Pa} + 39{,}200 \text{ Pa} = 45{,}200 \text{ Pa}$$

But $p_1 - p_2 = \rho g h$, where h is the height of the standing water column. Thus

$$h = \frac{45{,}200 \text{ Pa}}{\left(1000 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)} = 4.61 \text{ m}$$

15.64. Model: The ideal fluid obeys Bernoulli's equation.

Visualize: Please refer to Figure P15.64. There is a streamline connecting point 1 in the wider pipe on the left with point 2 in the narrower pipe on the right. The air speeds at points 1 and 2 are v_1 and v_2 and the cross-sectional area of the pipes at these points are A_1 and A_2. Points 1 and 2 are at the same height, so $y_1 = y_2$.

Solve: The volume flow rate is $Q = A_1 v_1 = A_2 v_2 = 1200 \times 10^{-6}\ \text{m}^3/\text{s}$. Thus

$$v_2 = \frac{1200 \times 10^{-6}\ \text{m}^3/\text{s}}{\pi(0.0020\ \text{m})^2} = 95.49\ \text{m/s} \qquad v_1 = \frac{1200 \times 10^{-6}\ \text{m}^3/\text{s}}{\pi(0.010\ \text{m})^2} = 3.82\ \text{m/s}$$

Now we can use Bernoulli's equation to connect points 1 and 2:

$$p_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$$\Rightarrow p_1 - p_2 = \tfrac{1}{2}\rho\left(v_2^2 - v_1^2\right) + \rho g\left(y_2 - y_1\right) = \tfrac{1}{2}\left(1.28\ \text{kg/m}^3\right)\left[(95.49\ \text{m/s})^2 - (3.82\ \text{m/s})^2\right] + 0\ \text{Pa} = 5826\ \text{Pa}$$

Because the pressure above the mercury surface in the right tube is p_2 and in the left tube is p_1, the difference in the pressures p_1 and p_2 is $\rho_{\text{Hg}} g h$. That is,

$$p_1 - p_2 = 5826\ \text{Pa} = \rho_{\text{Hg}} g h \Rightarrow h = \frac{5826\ \text{Pa}}{\left(13600\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)} = 4.37\ \text{cm}$$

15.67. Model: Treat water as an ideal fluid that obeys Bernoulli's equation. There is a streamline connecting the top of the tank with the hole.

Visualize: Please refer to Figure P15.67. We placed the origin of the coordinate system at the bottom of the tank so that the top of the tank (point 1) is at a height of h + 1.0 m and the hole (point 2) is at a height h. Both points 1 and 2 are at atmospheric pressure.

Solve: **(a)** Bernoulli's equation connecting points 1 and 2 is

$$p_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$$\Rightarrow p_{\text{atmos}} + \tfrac{1}{2}\rho v_1^2 + \rho g(h + 1.0\text{ m}) = p_{\text{atmos}} + \tfrac{1}{2}\rho v_2^2 + \rho g h$$

$$\Rightarrow v_2^2 - v_1^2 = 2g(1.0\text{ m}) = 19.6\text{ m}^2/\text{s}^2$$

Using the continuity equation $A_1 v_1 = A_2 v_2$,

$$v_1 = \left(\frac{A_2}{A_1}\right)v_2 = \frac{\pi(2.0\times10^{-3}\text{ m})^2}{\pi(1.0\text{ m})^2}v_2 = \frac{v_2}{250{,}000}$$

Because $v_1 \ll v_2$, we can simply put $v_1 \approx 0$ m/s. Bernoulli's equation thus simplifies to

$$v_2^2 = 19.6\text{ m}^2/\text{s}^2 \Rightarrow v_2 = 4.43\text{ m/s}$$

Therefore, the volume flow rate through the hole is

$$Q = A_2 v_2 = \pi(2.0\times10^{-3}\text{ m})^2(4.43\text{ m/s}) = 5.56\times10^{-5}\text{ m}^3/\text{s} = 3.34\text{ L/min}$$

(b) The rate at which the water level will drop is

$$v_1 = \frac{v_2}{250{,}000} = \frac{4.43\text{ m/s}}{250{,}000} = 1.77\times10^{-2}\text{ mm/s} = 1.06\text{ mm/min}$$

Assess: Because the hole through which water flows out of the tank has a diameter of only 4.0 mm, a drop in the water level at the rate of 1.06 mm/min is reasonable.