14-16. Letting $p_a = p_b$, we find $\rho_c g(H+T+D) + \rho_m(y-D) = \rho_c g(T) + \rho_m(y)$ and obtain

$$D = \frac{(H)\rho_c}{\rho_m - \rho_c} = \frac{(6.0\,\text{km})\left(2.9\,\text{g/cm}^3\right)}{3.3\,\text{g/cm}^3 - 2.9\,\text{g/cm}^3} = 43.5 \text{ km} .$$

14-18. (a) The force on face A of area A_A is

$$\begin{aligned} F_A &= p_A A_A = \rho_w g h_A A_A = 2\rho_w g d^3 \\ &= 2\left(1.0\times 10^3\,\text{kg/m}^3\right)\left(9.8\,\text{m/s}^2\right)(5.0\,\text{m})^3 = 2.45\times 10^6 \text{ N} . \end{aligned}$$

(b) The force on face B is

$$\begin{aligned} F_B &= \int_{2d}^{3d} p dA = \int_{2d}^{3d} \rho_w g z \times d\; dz = \rho_w g d \left[\frac{1}{2}z^2\right]_{2d}^{3d} = \frac{1}{2}\rho_w g d(9d^2 - 4d^2) \\ &= \frac{5}{2}\left(1.0\times 10^3\,\text{kg/m}^3\right)\left(9.8\,\text{m/s}^2\right)(5.0\,\text{m})^3 = 3.06\times 10^6 \text{ N} . \end{aligned}$$

Note that these figures are due to the "gauge" pressure only. If you add the contribution from the atmospheric pressure, then you need to add $F' = (1.0\times 10^5\,\text{Pa})(5.0\,\text{m})^2 = 2.5\times 10^6\,\text{N}$ to each of the figures above. The results would then be $5.0\times 10^6\,\text{N}$ and $5.6\times 10^6\,\text{N}$, respectively.

14-29. Since the object is in equilibrium:

Buoyant Force = weight of displaced fluid = weight of object

Let: ρ_w be the density of water, ρ_o be the density of oil, and ρ be the density of the object:

$$\frac{2}{3}\,V\rho_w g = V\rho g$$

So $\rho = \frac{2}{3}\,\rho_w = 667\text{ kg/m}^3$, and

$$0.9\,V\rho_o g = V\rho g = V\,\frac{2}{3}\,\rho_w g$$

So $\rho_o = \frac{2}{0.9\cdot 3}\,\rho_w = 741\text{ kg/m}^3$

14-53. (a) The friction force is

$$\begin{aligned} f &= A\Delta p = \rho_w g h A \\ &= \left(1.0\times 10^3\,\text{kg/m}^3\right)\left(9.8\,\text{m/s}^2\right)(6.0\text{m})\left(\frac{\pi}{4}\right)(0.040\,\text{m})^2 = 73.9 \text{ N} . \end{aligned}$$

Note: I have seemingly neglected the slight variation in pressure on different parts of the plug; however in fact the extra pressure at a point slightly below the center of the plug will be compensated by the lower pressure at a point symmetrically above the center of the plug.

(b) The speed of water flowing out of the hole is $v = \sqrt{2gh}$. Thus, the volume of water flowing out of the pipe in $t = 3.0\,\text{h}$ is

$$\begin{aligned} V &= Avt = \frac{\pi d^2 v t}{4} \\ &= \frac{\pi}{4}(0.040\,\text{m})^2\sqrt{2\left(9.8\,\text{m/s}^2\right)(6.0\,\text{m})}(3.0\,\text{h})(3600\,\text{s/h}) \\ &= 147\text{ m}^3 . \end{aligned}$$

14-59. (a) Using the notation in the problem in the equation of continuity yiedls:

$$AV = av$$

and in Bernoulli's equation we have:

$$P_1 + \frac{1}{2}\,\rho V^2 = P_2 + \frac{1}{2}\,\rho v^2$$

SO:

$$\begin{aligned}\Delta P = P_1 - P_2 &= \frac{1}{2}\,\rho\left(v^2 - V^2\right)\\ &= \frac{1}{2}\,\rho\left((AV/a)^2 - V^2\right)\\ &= \frac{1}{2}\,\rho\left((A/a)^2 - 1\right)V^2\end{aligned}$$

Isolating V yields:

$$\frac{2\Delta P}{\rho\left((A/a)^2 - 1\right)} = V^2$$

or

$$\sqrt{\frac{2\Delta P}{\rho\left((A/a)^2 - 1\right)}} = V$$

(b)

$$\begin{aligned}V &= \sqrt{\frac{2\cdot 14\times 10^3\ \text{Pa}}{1000\ \text{kg/m}^3\left((2)^2 - 1\right)}}\\ &= \sqrt{\frac{2\cdot 14\ \text{N/m}^2}{3\ \text{kg/m}^3}}\\ &= 3.06\ \text{m/s}\end{aligned}$$

14-61. (a) Bernoulli's equation gives $p_A = p_B + \frac{1}{2}\rho_{\text{air}}v^2$. But $\Delta p = p_A - p_B = \rho g h$ in order to balance the pressure in the two arms of the U-tube. Thus $\rho g h = \frac{1}{2}\rho_{\text{air}}v^2$, or

$$v = \sqrt{\frac{2\rho g h}{\rho_{\text{air}}}}\ .$$

Note: we are neglecting here the weight of the air, i.e., a term $\rho_{\text{air}}gy$ in Bernoulli's equation and also treating air as an incompressible fluid. Is is OK since $\rho_{\text{air}} \ll \rho_{\text{alcohol}}$ and the speeds are much less than the speed of sound.

(b) The plane's speed relative to the air is

$$v = \sqrt{\frac{2\rho g h}{\rho_{\text{air}}}} = \sqrt{\frac{2\left(810\,\text{kg/m}^3\right)(9.8\,\text{m/s}^2)(0.260\,\text{m})}{1.03\,\text{kg/m}^3}} = 63.3\ \text{m/s}\ .$$