3–9 The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in Fig. P3–9. Determine the gage pressure of air in the tank if $h_1 = 0.2$ m, $h_2 = 0.3$ m, and $h_3 = 0.46$ m. Take the densities of water, oil, and mercury to be 1000 kg/m³, 850 kg/m³, and 13,600 kg/m³, respectively.

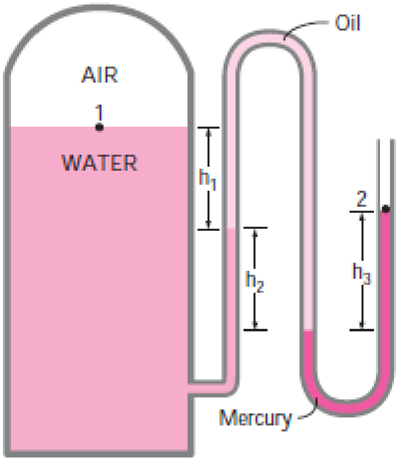


FIGURE P3–9

Analysis Starting with the pressure at point 1 at the air-water interface adding (as we go down) or subtracting (as we go up) the $\rho g h$ terms until result equal to P_{atm} since the tube is open to the atmosphere gives

$$P_1 + \rho_{water} g h_1 + \rho_{oil} g h_2 - \rho_{mercury} g h_3 = P_{atm}$$

Solving for P_1,

$$P_1 = P_{atm} - \rho_{water} g h_1 - \rho_{oil} g h_2 + \rho_{mercury} g h_3$$

or,

$$P_1 - P_{atm} = g(\rho_{mercury} h_3 - \rho_{water} h_1 - \rho_{oil} h_2)$$

Noting that $P_{1,gage} = P_1 - P_{atm}$ and substituting,

$$P_{1,gage} = (9.81\,\mathrm{m/s^2})[(13{,}600\,\mathrm{kg/m^3})(0.46\,\mathrm{m}) - (1000\,\mathrm{kg/m^3})(0.2\,\mathrm{m}) - (850\,\mathrm{kg/m^3})(0.3\,\mathrm{m})]\left(\frac{1\,\mathrm{N}}{1\,\mathrm{kg\cdot m/s^2}}\right)\left(\frac{1\,\mathrm{kPa}}{1000\,\mathrm{N/m^2}}\right)$$

$= \mathbf{56.9\ kPa}$

3–11 The gage pressure in a liquid at a depth of 3 m is read to be 28 kPa. Determine the gage pressure in the same liquid at a depth of 12 m.

Analysis The gage pressure at two different depths of

$$P_1 = \rho g h_1 \qquad \text{and} \qquad P_2 = \rho g h_2$$

Taking their ratio,

$$\frac{P_2}{P_1} = \frac{\rho g h_2}{\rho g h_1} = \frac{h_2}{h_1}$$

Solving for P_2 and substituting gives

$$P_2 = \frac{h_2}{h_1} P_1 = \frac{12 \text{ m}}{3 \text{ m}} (28 \text{ kPa}) = \mathbf{112\ \ kPa}$$

3–16 A vacuum gage connected to a tank reads 30 kPa at a location where the barometric reading is 755 mmHg. Determine the absolute pressure in the tank. Take ρ_{Hg} = 13,590 kg/m^3. *Answer: 70.6 kPa*

Analysis The atmospheric (or barometric) pressure can be expressed as

$$\begin{aligned} P_{atm} &= \rho g h \\ &= (13{,}590\ \text{kg/m}^3)(9.807\ \text{m/s}^2)(0.755\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) \\ &= 100.6\ \text{kPa} \end{aligned}$$

Then the absolute pressure in the tank becomes

$$P_{abs} = P_{atm} - P_{vac} = 100.6 - 30 = \mathbf{70.6\ \ kPa}$$

3-20 The basic barometer can be used to measure the height of a building. If the barometric readings at the top and at the bottom of a building are 730 and 755 mmHg, respectively, determine the height of the building. Assume an average air density of 1.18 kg/m³.

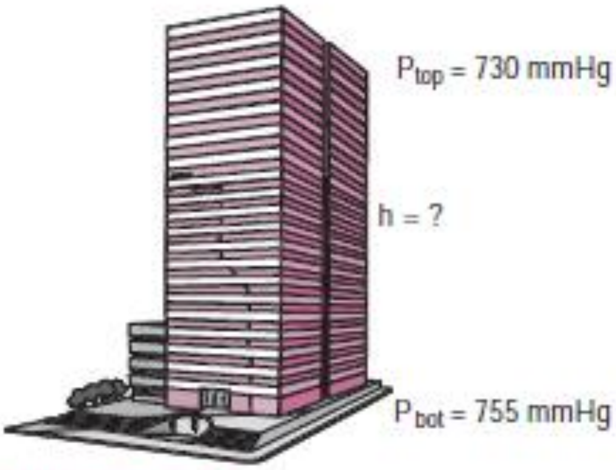


FIGURE P3–20

Analysis Atmospheric pressures at the top and at the bottom of the building are

$$\begin{aligned}P_{top} &= (\rho g h)_{top}\\ &= (13{,}600\ \text{kg/m}^3)(9.807\ \text{m/s}^2)(0.730\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right)\\ &= 97.36\ \text{kPa}\end{aligned}$$

$$\begin{aligned}P_{bottom} &= (\rho g h)_{bottom}\\ &= (13{,}600\ \text{kg/m}^3)(9.807\ \text{m/s}^2)(0.755\ \text{m})\left(\frac{1\text{N}}{1\text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right)\\ &= 100.70\ \text{kPa}\end{aligned}$$

Taking an air column between the top and the bottom of the building and writing a force l base area, we obtain

$$W_{air}/A = P_{bottom} - P_{top}$$

$$(\rho g h)_{air} = P_{bottom} - P_{top}$$

$$(1.18\ \text{kg/m}^3)(9.807\ \text{m/s}^2)(h)\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) = (100.70 - 97.36)\ \text{kPa}$$

It yields $h =$ **288.6 m**

3–29 A mercury manometer (ρ = 13,600 kg/m^3) is connected to an air duct to measure the pressure inside. The difference in the manometer levels is 15 mm, and the atmospheric pressure is 100 kPa. (a) Judging from Fig. P3–29, determine if the pressure in the duct is above or below the atmospheric pressure. (b) Determine the absolute pressure in the duct.

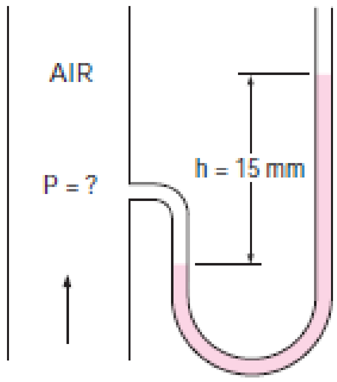


FIGURE P3–29

Analysis (*a*) The pressure in the duct is above atmospheric pressure since the fluid column on the duct side is at a lower level.

(*b*) The absolute pressure in the duct is determined from

$$
\begin{aligned}
P &= P_{atm} + \rho g h \\
&= (100 \text{ kPa}) + (13{,}600 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(0.015 \text{ m})\left(\frac{1 \text{ N}}{1 \text{ kg}\cdot\text{m/s}^2}\right)\left(\frac{1 \text{ kPa}}{1000 \text{ N/m}^2}\right) \\
&= \mathbf{102.0\ kPa}
\end{aligned}
$$

3–34 Consider a U-tube whose arms are open to the atmosphere. Now water is poured into the U-tube from one arm, and light oil (ρ = 790 kg/m³) from the other. One arm contains 70-cm-high water, while the other arm contains both fluids with an oil-to-water height ratio of 6. Determine the height of each fluid in that arm.

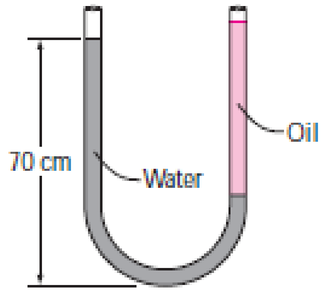


FIGURE P3–34

Analysis The height of water column in the left arm of the manometer is given to be h_{w1} = 0.70 m. We let the height of water and oil in the right arm to be h_{w2} and h_a, respectively. Then, $h_a = 6h_{w2}$. Noting that both arms are open to the atmosphere, the pressure at the bottom of the U-tube can be expressed as

$$P_{bottom} = P_{atm} + \rho_w g h_{w1} \quad \text{and} \quad P_{bottom} = P_{atm} + \rho_w g h_{w2} + \rho_a g h_a$$

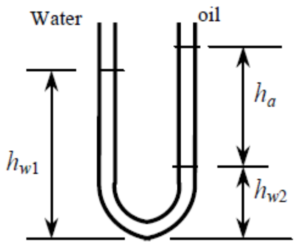
Setting them equal to each other and simplifying,

$$\rho_w g h_{w1} = \rho_w g h_{w2} + \rho_a g h_a \quad \rightarrow \quad \rho_w h_{w1} = \rho_w h_{w2} + \rho_a h_a \quad \rightarrow \quad h_{w1} = h_{w2} + (\rho_a / \rho_w) h_a$$

Noting that $h_a = 6h_{w2}$, the water and oil column heights in the second arm are determined to be

$$0.7\text{ m} = h_{w2} + (790/1000)6h_{w2} \quad \rightarrow \quad h_{w2} = \mathbf{0.122\ m}$$

$$0.7\text{ m} = 0.122\text{ m} + (790/1000)h_a \quad \rightarrow \quad h_a = \mathbf{0.732\ m}$$



Discussion Note that the fluid height in the arm that contains oil is higher. This is expected since oil is lighter than water.