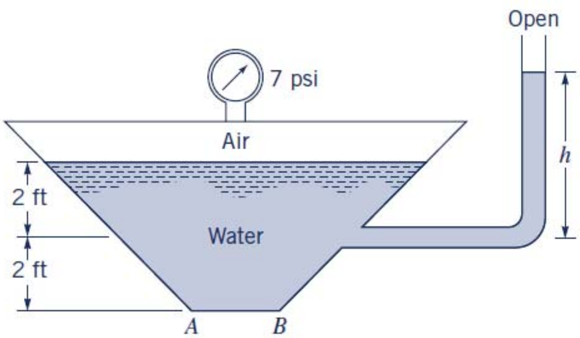
Problem 2.34
The closed tank of the figure below is filled with water and is 5 ft long. The pressure gage on the tank reads 7 psi. Determine: (**a**) the height, *h*, in the open water column, (**b**) the gage pressure acting on the bottom tank surface *AB*, and (**c**) the absolute pressure of the air in the top of the tank if the local atmospheric pressure is 14.7 psia.



Solution 2.34

$p = \gamma h + p_0$

(a) $p_1 = \gamma_{H_2O}(2\,\text{ft}) + p_{air}$

Also $p_1 = \gamma_{H_2O} h$ so that

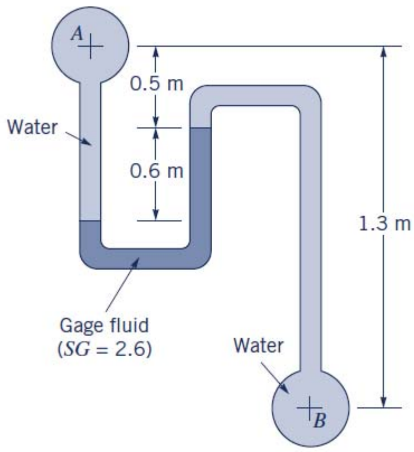
$$\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)h = \left(62.4\frac{\text{lb}}{\text{ft}^3}\right)(2\,\text{ft}) + \left(7\frac{\text{lb}}{\text{in.}^2}\right)\left(\frac{144\text{in.}^2}{\text{ft}^2}\right) \rightarrow \boxed{h = 18.2\text{ ft}}$$

(b) $$p_{AB} = \left[\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)(4\text{ft}) + \left(7\frac{\text{lb}}{\text{in.}^2}\right)\left(\frac{144\text{in.}^2}{\text{ft}^2}\right)\right]\left(\frac{1\text{ft}^2}{144\text{in.}^2}\right) \rightarrow \boxed{p = 8.73\text{ psi}}$$

(c) $p_{air} = 7\text{psi} + 14.7\,\text{psia} = \rightarrow \boxed{p_{air} = 21.7\text{psia}}$

Problem 2.40

Two pipes are connected by a manometer as shown in the figure below. Determine the pressure difference $p_A - p_B$, between the pipes.



Solution 2.40

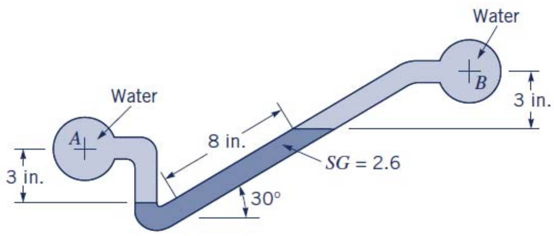
$$p_A + \gamma_{H_2O}(0.5\text{m} + 0.6\text{m}) - \gamma_{gf}(0.6\text{m}) + \gamma_{H_2O}(1.3\text{m} - 0.5\text{m}) = p_B$$

$$p_A - p_B = \gamma_{gf}(0.6\text{m}) - \gamma_{H_2O}(0.5\text{m} + 0.6\text{m} + 1.3\text{m} - 0.5\text{m})$$

$$= (2.6)\left(9.81\frac{\text{kN}}{\text{m}^3}\right)(0.6\text{m}) - \left(9.81\frac{\text{kN}}{\text{m}^3}\right)(1.9\text{m}) \rightarrow \boxed{p_A - p_B = -3.32 \text{ kPa}}$$

Problem 2.43

For the inclined-tube manometer of the figure below, the pressure in pipe *A* is 0.6 psi. The fluid in both pipes *A* and *B* is water, and the gage fluid in the manometer has a specific gravity of 2.6. What is the pressure in pipe *B* corresponding to the differential reading shown?



Solution 2.43

$$p_A + \gamma_{H_2O}\left(\frac{3}{12}\text{ft}\right) - \gamma_{gf}\left(\frac{8}{12}\text{ft}\right)\sin 30° - \gamma_{H_2O}\left(\frac{3}{12}\text{ft}\right) = p_B$$

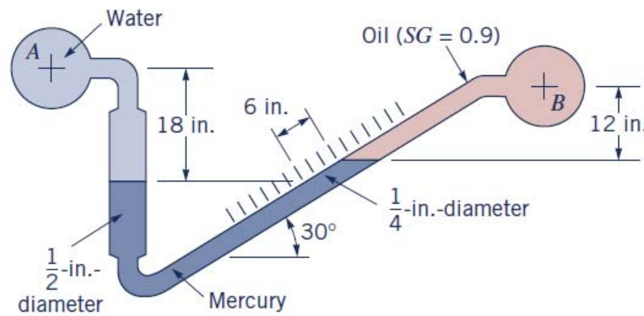
$$p_B = p_A - \gamma_{gf}\left(\frac{8}{12}\text{ft}\right)\sin 30°$$

$$= \left(0.6\frac{\text{lb}}{\text{in.}^2}\right)\left(144\frac{\text{in.}^2}{\text{ft}^2}\right) - (2.6)\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)\left(\frac{8}{12}\text{ft}\right)(0.5)$$

$$= 32.3\frac{\text{lb}}{\text{ft}^2} \times \frac{1\text{ ft}^2}{144\text{ ft}^2} \qquad \rightarrow \qquad \boxed{p_B = 0.224\text{ psi}}$$

Problem 2.64

Determine the change in the elevation of the mercury in the left leg of the manometer of the figure below as a result of an increase in pressure of 5 psi in pipe *A* while the pressure in pipe *B* remains constant.



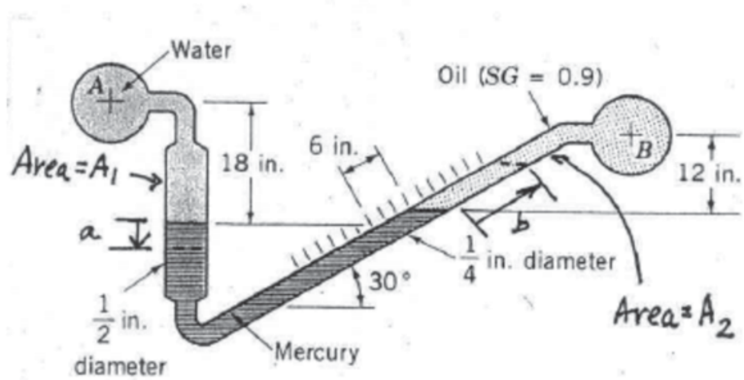
Solution 2.64

For the initial configuration:

$$p_A + \gamma_{H_2O}\left(\frac{18}{12}\right) - \gamma_{Hg}\left(\frac{6}{12}\sin 30°\right) - \gamma_{oil}\left(\frac{12}{12}\right) = p_B \qquad (1)$$

Where all lengths are in ft.

When p_A increases to p'_A the left column falls by the distance, a, and the right column moves up the dance, b, as shown in the figure.



For the final configuration:

$$p'_A + \gamma_{H_2O}\left(\frac{18}{12} + a\right) - \gamma_{Hg}\left(a + \frac{6}{12}\sin 30° + b\sin 30°\right) - \gamma_{oil}\left(\frac{12}{12} - b\sin 30°\right) = p_B \qquad (2)$$

Subtract Eq.(1) from Eq.(2) to obtain

$$p'_A - p_A + \gamma_{H_2O}(a) - \gamma_{Hg}(a + b\sin 30°) + \gamma_{oil}(b\sin 30°) = 0 \qquad (3)$$

The volume of liquid must be constant: $A_1 a = A_2 b$,

$$\left(\frac{1}{2}\text{in.}\right)^2 a = \left(\frac{1}{4}\text{in.}\right)^2 b \rightarrow b = 4a$$

Thus, Eq.(3) can be written as

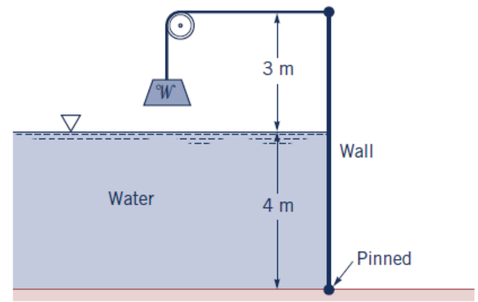
$$p'_A - p_A + \gamma_{H_2O}(a) - \gamma_{Hg}(a + 4a\sin 30°) + \gamma_{oil}(4a\sin 30°) = 0$$

$$a = \frac{-(p'_A - p_A)}{\gamma_{H_2O} - \gamma_{Hg}(3) + \gamma_{oil}(2)} = \frac{-\left(5\dfrac{\text{lb}}{\text{in.}^2}\right)\left(144\dfrac{\text{in.}^2}{\text{ft}^2}\right)}{62.4\dfrac{\text{lb}}{\text{ft}^3} - \left(847\dfrac{\text{lb}}{\text{ft}^3}\right)(3) + (0.9)\left(62.4\dfrac{\text{lb}}{\text{ft}^3}\right)(2)}$$

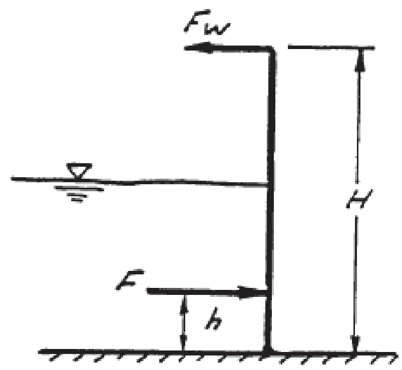
$$\boxed{a = 0.304 \text{ ft down}}$$

Problem 2.76

Find the weight W needed to hold the wall shown in the figure below upright. The wall is $10\ \text{m}$ wide.



Solution 2.76



The hydrostatic force F on the wall is found from

$$\begin{aligned} F &= \rho g h_c A \\ &= \left(1000\frac{\text{kg}}{\text{m}^3}\right)\left(9.81\frac{\text{m}}{\text{s}^2}\right)(2\text{m})\left(4\times 10\text{m}^2\right) \\ &= 78500\left(\frac{\text{kg}\cdot\text{m}}{\text{s}^2}\right)\left(\frac{\text{kN}}{1000\,\text{N}}\right) \\ &= 785\,\text{kN} \end{aligned}$$

The force F is located one-third of the water depth from the bottom of the water.

$$h = \frac{1}{3}(4\text{m}) = 1.33\text{m}$$

Summing moments about the pinned joint,

$$F_W = \frac{h}{H}F = \frac{(1.33\,\text{m})}{(7\,\text{m})}(785\,\text{kN}) = 149\,\text{kN}$$

Assuming no friction between the rope and the pulley,

$$W = F_W \quad \rightarrow \quad \boxed{W = 149\ \text{kN}}$$

DISCUSSION

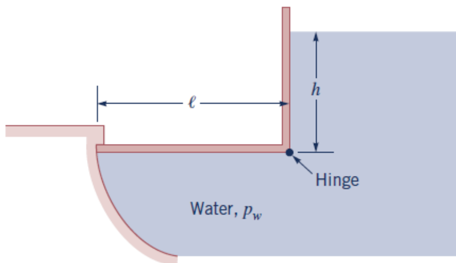
Note that the atmospheric pressure acts on both sides of the wall.

Therefore, the forces due to atmospheric pressure are equal and opposite, and cancel.

Problem 2.79

Consider the gate shown in the figure below. The gate is massless and has a width b (perpendicular to the paper). The hydrostatic pressure on the vertical side creates a counterclockwise moment about the hinge, and the hydrostatic pressure on the horizontal side (or bottom) creates a clockwise moment about the hinge. Show that the net clockwise moment is

$$\sum u = \rho_w ghb\left(\frac{\ell^2}{2} - \frac{h^2}{6}\right).$$



Solution 2.79

The vertical force on the horizontal side is

$$F_v = \rho_w ghA = \rho_w gh\left(l \times b\right)$$

Constant force →resultant acts at midpoint

The horizontal force on the vertical side is

$$F_H = \rho_w gh_c A = \rho_w g\left(\frac{h}{2}\right)\left(h \times b\right)$$

The resultant acts at

$$y_p = y_c + \frac{I_{xc}}{y_c A} = \frac{h}{2} + \frac{\frac{1}{12}bh^3}{\frac{h}{2}(bh)} = \frac{h}{2} + \frac{h}{6} = \frac{2h}{3}$$

Summing moments about the hinge

$$\overset{\curvearrowright}{+}\sum M = F_v x_p - F_H\left(h - y_p\right) = \rho_w ghlb\left(\frac{l}{2}\right) - \frac{\rho_w gh^2 b}{2}\left(\frac{h}{3}\right)$$

$$\rightarrow \boxed{\overset{\curvearrowright}{+}\sum M = \rho_w ghb\left(\frac{l^2}{2} - \frac{h^2}{6}\right)}$$