2.5

2.5 An unknown immiscible liquid seeps into the bottom of an open oil tank. Some measurements indicate that the depth of the unknown liquid is 1.5 m and the depth of the oil (specific weight = 8.5 kN/m³) floating on top is 5.0 m. A pressure gage connected to the bottom of the tank reads 65 kPa. What is the specific gravity of the unknown liquid?

$$p_{bottom} = (\gamma_{oil})(5\,m) + (\gamma_u)(1.5\,m) \quad \text{where } \gamma_u \sim \text{unknown liquid } \gamma$$

$$\gamma_u = \frac{p_{bottom} - (\gamma_{oil})(5\,m)}{1.5\,m} = \frac{65\times 10^3 \frac{N}{m^2} - \left(8.5\times 10^3 \frac{N}{m^3}\right)(5\,m)}{1.5\,m}$$

$$= 15\times 10^3 \frac{N}{m^3}$$

$$SG = \frac{\gamma_u}{\gamma_{H_2O@4^\circ C}} = \frac{15\times 10^3 \frac{N}{m^3}}{9.81\times 10^3 \frac{N}{m^3}} = \underline{\underline{1.53}}$$

2.9

2.9 **Bathyscaphes are capable of submerging to great depths in the ocean. What is the pressure at a depth of 5 km, assuming that seawater has a constant specific weight of 10.1 kN/m³? Express your answer in pascals and psi.**

$$p = \gamma h + p_0$$

At the surface $p_0 = 0$ so that

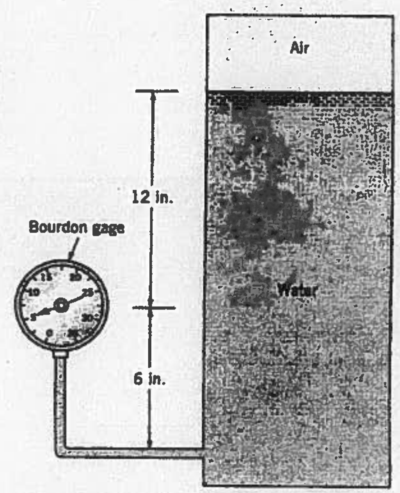
$$p = \left(10.1 \times 10^3 \frac{N}{m^3}\right)\left(5 \times 10^3 m\right) = 50.5 \times 10^6 \frac{N}{m^2} = \underline{\underline{50.5\ MPa}}$$

Also,

$$p = \left(50.5 \times 10^6 \frac{N}{m^2}\right)\left(1.450 \times 10^{-4} \frac{\frac{lb}{in.^2}}{\frac{N}{m^2}}\right) = \underline{\underline{7320\ psi}}$$

2.27

2.27 Bourdon gages (see Video V2.4 and Fig. 2.13) are commonly used to measure pressure. When such a gage is attached to the closed water tank of Fig. P2.27 the gage reads 5 psi. What is the absolute air pressure in the tank? Assume standard atmospheric pressure of 14.7 psi.



■ FIGURE P2.27

$$p = \gamma h + p_o$$

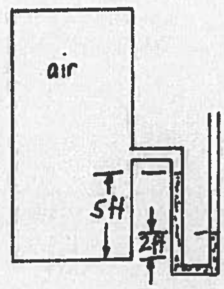
$$p_{gage} - \left(\frac{12}{12}\,ft\right)\gamma_{H_2O} = p_{air}$$

$$p_{air} = \left(5\,\frac{lb}{in.^2} + 14.7\,\frac{lb}{in.^2}\right) - \frac{(1\,ft)(62.4\,\frac{lb}{ft^3})}{144\,\frac{in.^2}{ft^2}}$$

$$p_{air} = \underline{\underline{19.3\ psia}}$$

2.31

2.31 A water-filled U-tube manometer is used to measure the pressure inside a tank that contains air. The water level in the U-tube on the side that connects to the tank is 5 ft above the base of the tank. The water level in the other side of the U-tube (which is open to the atmosphere) is 2 ft above the base. Determine the pressure within the tank.



$$p_{air} + \gamma_{H_2O}(5\,ft) - \gamma_{H_2O}(2\,ft) = 0$$

or

$$p_{air} = -(3\,ft)\gamma_{H_2O} = -(3\,ft)(62.4\,\tfrac{lb}{ft^3})$$

$$= \underline{\underline{-187\,\tfrac{lb}{ft^2}}}$$

2.32

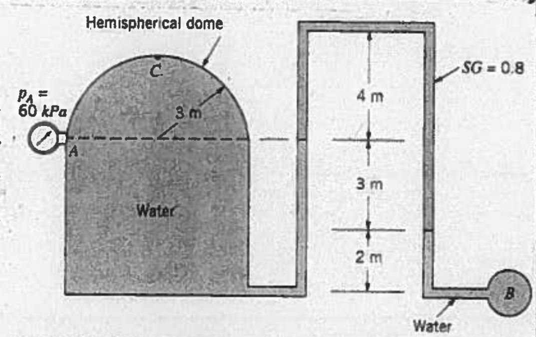
2.32 A barometric pressure of 29.4 in. Hg corresponds to what value of atmospheric pressure in psia, and in pascals?

(In psi) $p = \gamma h = \left(847 \frac{lb}{ft^3}\right)\left(\frac{29.4}{12} ft\right)\left(\frac{1 ft^2}{144 in.^2}\right) = \underline{\underline{14.4 \text{ psia}}}$

(In Pa) $p = \gamma h = \left(133 \times 10^3 \frac{N}{m^3}\right)(29.4 in.)\left(2.540 \times 10^{-2} \frac{m}{in.}\right) = \underline{\underline{99.3 \text{ kPa (abs)}}}$

2.39

2.39 A closed cylindrical tank filled with water has a hemispherical dome and is connected to an inverted piping system as shown in Fig. P2.39. The liquid in the top part of the piping system has a specific gravity of 0.8, and the remaining parts of the system are filled with water. If the pressure gage reading at A is 60 kPa, determine: (a) the pressure in pipe B, and (b) the pressure head, in millimeters of mercury, at the top of the dome (point C).



■ FIGURE P2.39

(a)
$$p_A + (SG)(\gamma_{H_2O})(3\,m) + \gamma_{H_2O}(2\,m) = p_B$$
$$p_B = 60\,kPa + (0.8)(9.81\times10^3\,\tfrac{N}{m^3})(3\,m) + (9.80\times10^3\,\tfrac{N}{m^3})(2\,m)$$
$$= \underline{\underline{103\ kPa}}$$

(b)
$$p_C = p_A - \gamma_{H_2O}(3\,m)$$
$$= 60\,kPa - (9.80\times10^3\,\tfrac{N}{m^3})(3\,m)$$
$$= 30.6\times10^3\,\tfrac{N}{m^2}$$
$$h = \frac{p_C}{\gamma_{Hg}} = \frac{30.6\times10^3\,\frac{N}{m^2}}{133\times10^3\,\frac{N}{m^3}} = 0.230\,m$$
$$= 0.230\,m\left(\frac{10^3\,mm}{m}\right) = \underline{\underline{230\ mm}}$$

2.40

2.40 Two pipes are connected by a manometer as shown in Fig. P2.40. Determine the pressure difference, $p_A - p_B$, between the pipes.

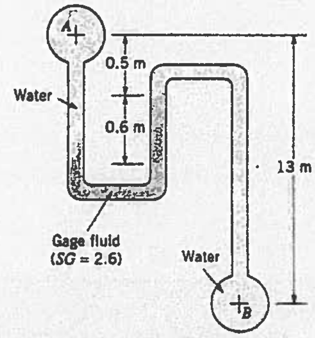


FIGURE P2.40

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

Thus,

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

$$= (2.6)\left(9.81\,\frac{kN}{m^3}\right)(0.6\,m) - \left(9.80\,\frac{kN}{m^3}\right)(1.9\,m)$$

$$= \underline{\underline{-\,3.32\ kPa}}$$

2.43

2.43 For the inclined-tube manometer of Fig. P2.43 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?

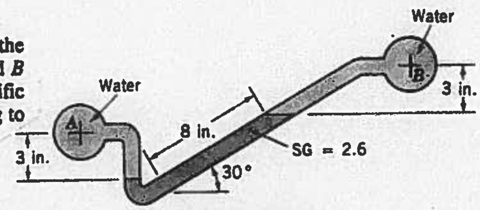


FIGURE P2.43

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

(where γ_{gf} is the specific weight of the gage fluid)

Thus,

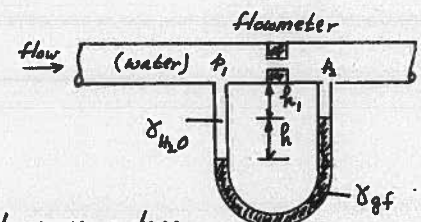
$$p_B = p_A - \gamma_{gf}\left(\tfrac{8}{12}\text{ ft}\right)\sin 30°$$

$$= \left(0.6\,\frac{\text{lb}}{\text{in.}^2}\right)\left(144\,\frac{\text{in.}^2}{\text{ft}^2}\right) - (2.6)\left(62.4\,\frac{\text{lb}}{\text{ft}^3}\right)\left(\tfrac{8}{12}\text{ ft}\right)(0.5) = 32.3\,\frac{\text{lb}}{\text{ft}^2}$$

$$= 32.3\ \text{lb/ft}^2 / 144\ \text{in.}^2/\text{ft}^2 = \underline{\underline{0.224\ \text{psi}}}$$

2.44

2.44 A flowrate measuring device is installed in a horizontal pipe through which water is flowing. A U-tube manometer is connected to the pipe through pressure taps located 3 in. on either side of the device. The gage fluid in the manometer has a specific weight of 112 lb/ft³. Determine the differential reading of the manometer corresponding to a pressure drop between the taps of 0.5 lb/in.².



Let p_1 and p_2 be pressures at pressure taps.
Write manometer equation between p_1 and p_2. Thus,

$$p_1 + \gamma_{H_2O}(h_1 + h) - \gamma_{gf}\,h - \gamma_{H_2O}\,h_1 = p_2$$

so that

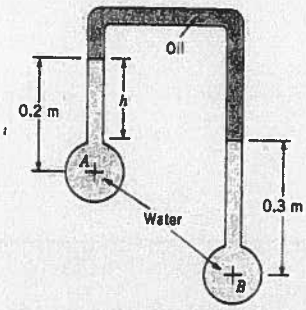
$$h = \frac{p_1 - p_2}{\gamma_{gf} - \gamma_{H_2O}} = \frac{\left(0.5\,\frac{\text{lb}}{\text{in.}^2}\right)\left(144\,\frac{\text{in.}^2}{\text{ft}^2}\right)}{112\,\frac{\text{lb}}{\text{ft}^3} - 62.4\,\frac{\text{lb}}{\text{ft}^3}}$$

$$= \underline{\underline{1.45\ \text{ft}}}$$

21 bi

2.53

2.53 The inverted U-tube manometer of Fig. P2.53 contains oil ($SG = 0.9$) and water as shown. The pressure differential between pipes A and B, $p_A - p_B$, is -5 kPa. Determine the differential reading, h.



■ FIGURE P2.53

$$p_A - \gamma_{H_2O}(0.2m) + \gamma_{oil}(h) + \gamma_{H_2O}(0.3m) = p_B$$

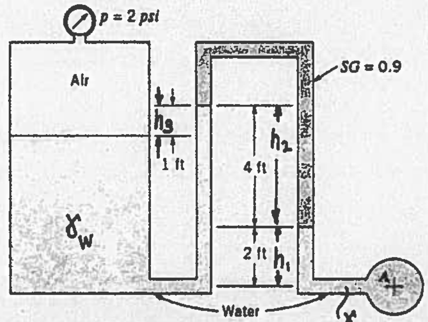
Thus,

$$h = \frac{(p_B - p_A) + \gamma_{H_2O}(0.2m) - \gamma_{H_2O}(0.3m)}{\gamma_{oil}}$$

$$= \frac{5\times10^3\frac{N}{m^2} - (9.80\times10^3\frac{N}{m^3})(0.1m)}{8.95\times10^3\frac{N}{m^3}} = \underline{\underline{0.449\ m}}$$

2.56

2.56 Determine the pressure of the water in pipe A shown in Fig. P2.56 if the gage pressure of the air in the tank is 2 psi.



■ FIGURE P2.56

$$p_A - \gamma_w h_1 - (0.9\gamma_w)h_2 + \gamma_w h_3 = p_{air}$$

or

$$p_A = p_{air} + \gamma_w(h_1 + 0.9h_2 - h_3)$$

$$= 2\,\frac{\text{lb}}{\text{in.}^2}\left(\frac{144\,\text{in.}^2}{\text{ft}^2}\right) + 62.4\,\frac{\text{lb}}{\text{ft}^3}(\cdot\ \text{ft} + 0.9(4\,\text{ft}) - 1\,\text{ft})$$

$$= \underline{\underline{575\,\frac{\text{lb}}{\text{ft}^2}}}$$

2.58

2.58 In Fig. P2.58 pipe *A* contains gasoline ($SG = 0.7$), pipe *B* contains oil ($SG = 0.9$), and the manometer fluid is mercury. Determine the new differential reading if the pressure in pipe *A* is decreased 25 kPa, and the pressure in pipe *B* remains constant. The initial differential reading is 0.30 m as shown.

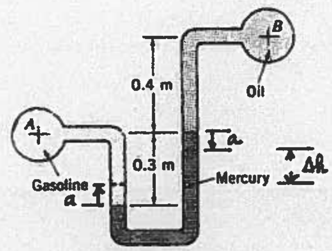


FIGURE P2.58

For the initial configuration:

$$p_A + \gamma_{gas}(0.3\,m) - \gamma_{Hg}(0.3\,m) - \gamma_{oil}(0.4\,m) = p_B \qquad (1)$$

With a decrease in p_A to p_A' gage fluid levels change as shown on figure. Thus, for final configuration:

$$p_A' + \gamma_{gas}(0.3-a) - \gamma_{Hg}(\Delta h) - \gamma_{oil}(0.4+a) = p_B \qquad (2)$$

where all lengths are in m. Subtract Eq.(2) from Eq.(1) to obtain,

$$p_A - p_A' + \gamma_{gas}(a) - \gamma_{Hg}(0.3-\Delta h) + \gamma_{oil}(a) = 0 \qquad (3)$$

Since $2a + \Delta h = 0.3$ (see figure) then

$$a = \frac{0.3-\Delta h}{2}$$

and from Eq.(3)

$$p_A - p_A' + \gamma_{gas}\left(\frac{0.3-\Delta h}{2}\right) - \gamma_{Hg}(0.3-\Delta h) + \gamma_{oil}\left(\frac{0.3-\Delta h}{2}\right) = 0$$

Thus,

$$\Delta h = \frac{p_A - p_A' + \gamma_{gas}(0.15) - \gamma_{Hg}(0.3) + \gamma_{oil}(0.15)}{-\gamma_{Hg} + \frac{\gamma_{gas}}{2} + \frac{\gamma_{oil}}{2}}$$

and with $p_A - p_A' = 25\,kPa$

$$\Delta h = \frac{25\frac{kN}{m^2} + (0.7)(9.81\frac{kN}{m^3})(0.15\,m) - (133\frac{kN}{m^3})(0.3\,m) + (0.9)(9.81\frac{kN}{m^3})(0.15\,m)}{-133\frac{kN}{m^3} + \frac{(0.7)(9.81\frac{kN}{m^3})}{2} + \frac{(0.9)(9.81\frac{kN}{m^3})}{2}}$$

$$= \underline{\underline{0.100\ m}}$$

2.59

2.59 The mercury manometer of Fig. P2.59 indicates a differential reading of 0.30 m when the pressure in pipe *A* is 30 mm Hg vacuum. Determine the pressure in pipe *B*.

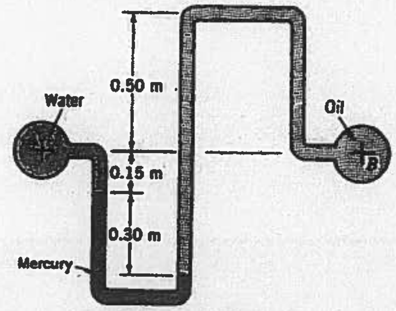


FIGURE P2.59

$$p_B + \gamma_{oil}\,(0.15\,m + 0.30\,m) - \gamma_{Hg}\,(0.3\,m) - \gamma_{H_2O}\,(0.15\,m) = p_A$$

where $p_A = -\gamma_{Hg}\,(0.030\,m)$

Thus,

$$p_B = -\gamma_{Hg}\,(0.030\,m) - \gamma_{oil}\,(0.45\,m) + \gamma_{Hg}\,(0.3\,m) + \gamma_{H_2O}\,(0.15\,m)$$

$$= -\left(133\,\frac{kN}{m^3}\right)(0.030\,m) - \left(8.95\,\frac{kN}{m^3}\right)(0.45\,m) + \left(133\,\frac{kN}{m^3}\right)(0.3\,m) + \left(9.80\,\frac{kN}{m^3}\right)(0.15\,m)$$

$$= \underline{\underline{33.4\ kPa}}$$

2.62

2.62 Determine the new differential reading along the inclined leg of the mercury manometer of Fig. P2.62, if the pressure in pipe A is decreased 10 kPa and the pressure in pipe B remains unchanged. The fluid in A has a specific gravity of 0.9 and the fluid in B is water.

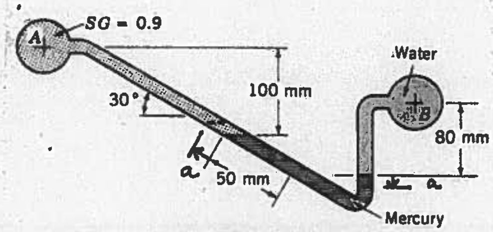


FIGURE P2.62

For the initial configuration:

$$p_A + \gamma_A(0.1) + \gamma_{Hg}(0.05 \sin 30°) - \gamma_{H_2O}(0.08) = p_B \qquad (1)$$

where all lengths are in m. When p_A decreases left column moves up a distance, a, and right column moves down a distance, a, as shown in figure. For the final configuration:

$$p_A' + \gamma_A(0.1 - a \sin 30°) + \gamma_{Hg}(a \sin 30° + 0.05 \sin 30° + a) - \gamma_{H_2O}(0.08 + a) = p_B \qquad (2)$$

where p_A' is the new pressure in pipe A.
Subtract Eq.(2) from Eq.(1) to obtain

$$p_A - p_A' + \gamma_A(a \sin 30°) - \gamma_{Hg}\, a(\sin 30° + 1) + \gamma_{H_2O}(a) = 0$$

Thus,

$$a = \frac{-(p_A - p_A')}{\gamma_A \sin 30° - \gamma_{Hg}(\sin 30° + 1) + \gamma_{H_2O}}$$

For $p_A - p_A' = 10 \text{ kPa}$

$$a = \frac{-10 \frac{kN}{m^2}}{(0.9)(9.81 \frac{kN}{m^3})(0.5) - (133 \frac{kN}{m^3})(0.5+1) + 9.80 \frac{kN}{m^3}}$$

$$= 0.0540 \text{ m}$$

New differential reading, Δh, measured along inclined tube is equal to

$$\Delta h = \frac{a}{\sin 30°} + 0.05 + a$$

$$= \frac{0.0540 \text{ m}}{0.5} + 0.05 \text{ m} + 0.0540 \text{ m} = \underline{\underline{0.212 \text{ m}}}$$

2.73

2.73 A piston having a cross-sectional area of $0.07\ m^2$ is located in a cylinder containing water as shown in Fig. P2.73. An open U-tube manometer is connected to the cylinder as shown. For $h_1 = 60$ mm and $h = 100$ mm, what is the value of the applied force, P, acting on the piston? The weight of the piston is negligible.

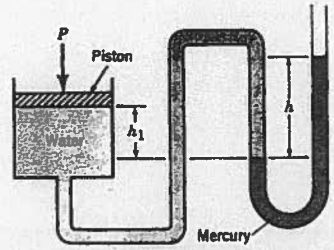


FIGURE P2.73

For equilibrium, $P = p_p A_p$ where p_p is the pressure acting on piston and A_p is the area of the piston. Also,

$$p_p + \gamma_{H_2O} h_1 - \gamma_{Hg} h = 0$$

or

$$p_p = \gamma_{Hg} h - \gamma_{H_2O} h_1$$

$$= \left(133 \frac{kN}{m^3}\right)(0.100\,m) - \left(9.80 \frac{kN}{m^3}\right)(0.060\,m)$$

$$= 12.7 \frac{kN}{m^2}$$

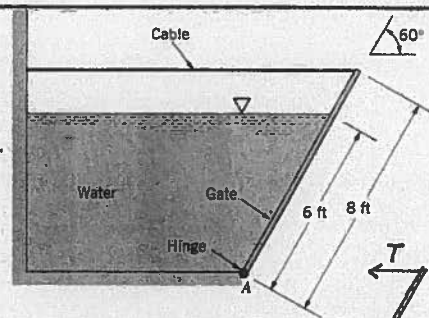
Thus,

$$P = \left(12.7 \times 10^3 \frac{N}{m^2}\right)(0.07\,m^2) = \underline{\underline{889\ N}}$$

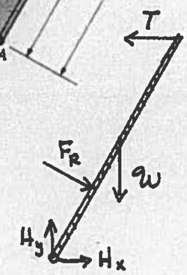
41 bi

2.87

2.87 A homogeneous, 4-ft-wide, 8-ft-long rectangular gate weighing 800 lb is held in place by a horizontal flexible cable as shown in Fig. P2.87. Water acts against the gate which is hinged at point *A*. Friction in the hinge is negligible. Determine the tension in the cable.



■ FIGURE P2.87



$F_R = \gamma h_c A \quad \text{where } h_c = \left(\frac{6 ft}{2}\right) \sin 60°$

Thus,

$$F_R = \left(62.4 \frac{lb}{ft^3}\right)\left(\frac{6 ft}{2}\right)(\sin 60°)(6 ft \times 4 ft)$$

$$= 3890 \text{ lb}$$

To locate F_R,

$$y_R = \frac{I_{xc}}{y_c A} + y_c \qquad \text{where } y_c = 3 ft$$

so that

$$y_R = \frac{\frac{1}{12}(4 ft)(6 ft)^3}{(3 ft)(6 ft \times 4 ft)} + 3 ft = 4.0 ft$$

For equilibrium,

$$\Sigma M_H = 0$$

and

$$T\,(8 ft)(\sin 60°) = \mathcal{W}\,(4 ft)(\cos 60°) + F_R\,(2 ft)$$

$$T = \frac{(800 lb)(4 ft)(\cos 60°) + (3890 lb)(2 ft)}{(8 ft)(\sin 60°)}$$

$$= \underline{\underline{1350 \text{ lb}}}$$

2.88

2.88 A rectangular gate 6 ft tall and 5 ft wide in the side of an open tank is held in place by the force F as indicated in Fig. P2.88. The weight of the gate is negligible, and the hinge at O is frictionless. (a) Determine the water depth, h, if the resultant hydrostatic force of the water acts 2.5 ft above the bottom of the gate, i.e., it is collinear with the applied force F. (b) For the depth of part (a), determine the magnitude of the resultant hydrostatic force. (c) Determine the force that the hinge puts on the gate under the above conditions.

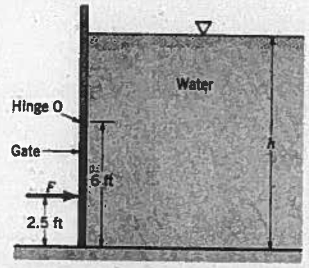


FIGURE P2.88

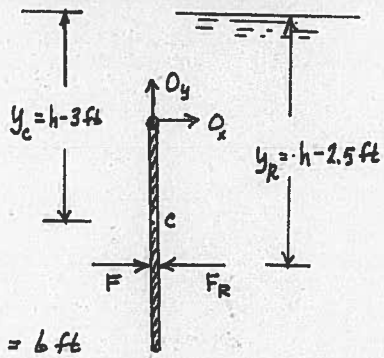
(a)

$$y_R - y_c = \frac{I_{xc}}{y_c A}$$

$$(h - 2.5\,ft) - (h - 3.0\,ft) = \frac{\frac{1}{12}(5\,ft)(6\,ft)^3}{(h - 3\,ft)(6\,ft \times 5\,ft)}$$

$$0.5\,ft = \frac{3\,ft^2}{h - 3\,ft}$$

$$h = \underline{\underline{9.00\,ft}}$$



(b) $F_R = \gamma h_c A$ where $h_c = h - 3\,ft = 6\,ft$

$$= (62.4\,\tfrac{lb}{ft^3})(6\,ft)(6\,ft \times 5\,ft)$$

$$= \underline{\underline{11{,}200\,lb}}$$

(c) For equilibrium,

$$\Sigma M_o = 0$$

So that

$$F\,(3.5\,ft) = F_R\,(3.5\,ft)$$

$$F = F_R$$

$$\Sigma F_x = 0$$

$$O_x + F - F_R = 0$$

$$\underline{\underline{O_x = 0}}$$

$$\Sigma F_y = 0 \qquad \underline{\underline{O_y = 0}}$$

2.95

2.95 A gate having the cross section shown in Fig. P2.95 closes an opening 5 ft wide and 4 ft high in a water reservoir. The gate weighs 500 lb and its center of gravity is 1 ft to the left of AC and 2 ft above BC. Determine the horizontal reaction that is developed on the gate at C.

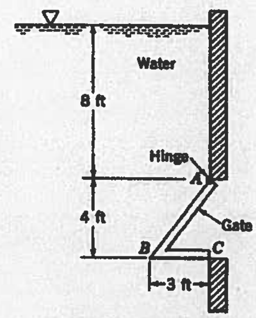


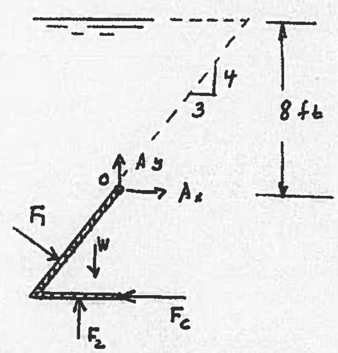
FIGURE P2.95

$F_1 = \gamma h_{c1} A_1$ where $h_{c1} = 8\,ft + 2\,ft$

Thus,

$F_1 = (62.4 \frac{lb}{ft^3})(10\,ft)(5\,ft \times 5\,ft)$

$= 15,600\ lb$



To locate F_1,

$$y_1 = \frac{I_{xc}}{y_{c1}A_1} + y_{c1}$$

where $y_{c1} = \dfrac{8\,ft}{\frac{4}{5}} + 2.5\,ft = 12.5\,ft$

So that

$$y_1 = \frac{\frac{1}{12}(5\,ft)(5\,ft)^3}{(12.5\,ft)(5\,ft \times 5\,ft)} + 12.5\,ft = 12.67\,ft$$

Also,

$F_2 = p_2 A_2$ where $p_2 = \gamma_{H_2O}\ (8\,ft + 4\,ft)$

so that

$F_2 = \gamma_{H_2O}\,(12\,ft)(A_2) = (62.4 \frac{lb}{ft^3})(12\,ft)(3\,ft \times 5\,ft) = 11,230\ lb$

For equilibrium,

$$\sum M_o = 0$$

and

$$F_1 \left(y_1 - \frac{8\,ft}{\frac{4}{5}}\right) + W(1\,ft) - F_2\left(\tfrac{1}{2}\right)(3\,ft) - F_C\,(4\,ft)$$

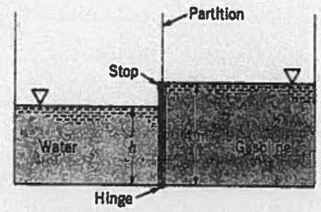
so that

$$F_C = \frac{(15,600\,lb)(12.67\,ft - 10\,ft) + (500\,lb)(1\,ft) - (11,230\,lb)(\frac{3}{2}\,ft)}{4\,ft} = \underline{\underline{6330\,lb}}$$

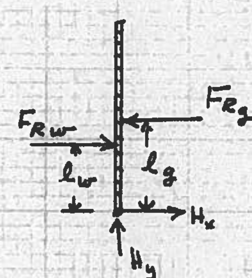
Master Typing Sheet
10% Reduction
8 1/2 x 11 trim size

2.99

2.99 An open tank has a vertical partition and on one side contains gasoline with a density $\rho = 700\ kg/m^3$ at a depth of 4 m, as shown in Fig. P2.99. A rectangular gate that is 4 m high and 2 m wide and hinged at one end is located in the partition. Water is slowly added to the empty side of the tank. At what depth, h, will the gate start to open?



■ FIGURE P2.99



$F_{R_g} = \gamma_g\, h_{c_g}\, A_g$

where g refers to gasoline.

$F_{R_g} = \left(700 \frac{kg}{m^3}\right)\left(9.81 \frac{m}{s^2}\right)(2m)(4m \times 2m)$

$= 110 \times 10^3\ N = 110\ kN$

$F_{R_w} = \gamma_w\, h_{c_w}\, A_w$

where w refers to water.

$F_{R_w} = \left(9.80 \times 10^3 \frac{N}{m^3}\right)\left(\frac{h}{2}\right)(2m \times h)$

where h is depth of water.

$F_{R_w} = (9.80 \times 10^3)\, h^2$

For equilibrium,

$\sum M_H = 0$

so that

$F_{R_w}\, l_w = F_{R_g}\, l_g \quad$ with $l_w = \frac{h}{3}$ and $l_g = \frac{4}{3}\ m$

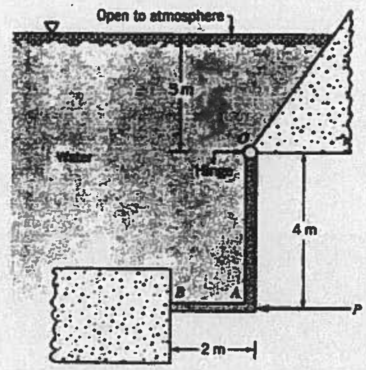
Thus, $(9.80 \times 10^3)(h^2)\left(\frac{h}{3}\right) = (110 \times 10^3\ N)\left(\frac{4}{3}\ m\right)$

and $\quad \underline{\underline{h = 3.55\ m}}$

which is the limiting value for h.

2.101

2.101 The rigid gate, OAB, of Fig. P2.101 is hinged at O and rests against a rigid support at B. What minimum horizontal force, P, is required to hold the gate closed if its width is 3 m? Neglect the weight of the gate and friction in the hinge. The back of the gate is exposed to the atmosphere.



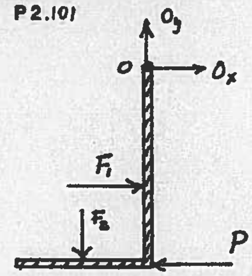
■ FIGURE P2.101

$F_1 = \gamma h_{c_1} A_1$, where $h_{c_1} = 5m$

Thus,
$F_1 = (9800 \frac{N}{m^3})(5m)(4m \times 3m)$
$= 5.88 \times 10^5 N$

$F_2 = \gamma h_{c_2} A_2$ where $h_{c_2} = 7m$

so that
$F_2 = (9800 \frac{N}{m^3})(7m)(2m \times 3m)$
$= 4.12 \times 10^5 N$



To locate F_1,

$$y_{R_1} = \frac{I_{xc}}{y_{c_1} A_1} + y_{c_1} = \frac{\frac{1}{12}(3m)(4m)^3}{(5m)(4m \times 3m)} + 5m = 5.267m$$

The force F_2 acts at the center of the AB section. Thus,

$$\sum M_O = 0$$

and

$$F_1 (5.267m - 3m) + F_2 (1m) = P (4m)$$

so that

$$P = \frac{(5.88 \times 10^5 N)(2.267m) + (4.12 \times 10^5 N)(1m)}{4 m}$$

$$= \underline{\underline{436 \, kN}}$$

2.102

2.102 A rectangular gate that is 2 m wide is located in the vertical wall of a tank containing water as shown in Fig. P2.102. It is desired to have the gate open automatically when the depth of water above the top of the gate reaches 10 m. (a) At what distance, d, should the frictionless horizontal shaft be located? (b) What is the magnitude of the force on the gate when it opens?

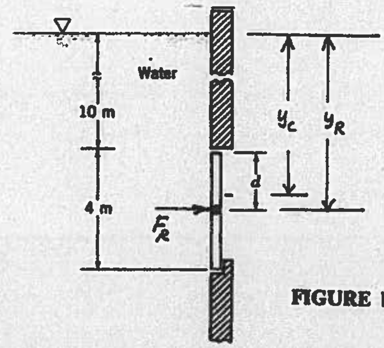


FIGURE P2.102

(a) As depth increases the center of pressure moves toward the centroid of the gate. If we locate hinge at y_R when depth $= 10\,m + d$, the gate will open automatically for any further increase in depth.

Since,

$$y_R = \frac{I_{xc}}{y_c A} + y_c = \frac{\frac{1}{12}(2m)(4m)^3}{(12m)(2m \times 4m)} + 12m = 12.11m$$

then

$$d = y_R - 10m = 12.11m - 10m = \underline{\underline{2.11\,m}}$$

(b) For the depth shown,

$$F_R = \gamma h_c A = \left(9.80 \frac{kN}{m^3}\right)(12m)(2m \times 4m) = \underline{\underline{941\,kN}}$$

2.116

2.116 A 4-m-long curved gate is located in the side of a reservoir containing water as shown in Fig. P2.116. Determine the magnitude of the horizontal and vertical components of the force of the water on the gate. Will this force pass through point A? Explain.

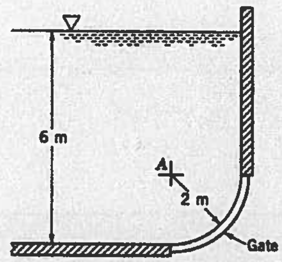
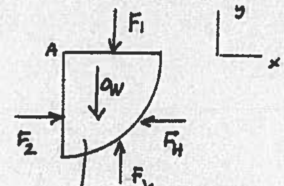


FIGURE P2.116



volume ~ $\forall$
and
$$\forall = \frac{\pi (2m)^2}{4} \times 4\,m = 4\pi\ m^3$$

For equilibrium,

$$\Sigma F_x = 0$$

or

$$F_H = F_2 = \gamma h_{c2} A_2 = \gamma (4m + 1m)(2m \times 4m)$$

so that

$$F_H = \left(9.80 \frac{kN}{m^3}\right)(5m)(8m^2) = \underline{\underline{392\ kN}}$$

Similarly,

$$\Sigma F_y = 0$$

$$F_V = F_1 + \mathcal{W} \qquad \text{where :}$$

$$F_1 = [\gamma (4m)](2m \times 4m) = \left(9.80 \frac{kN}{m^3}\right)(4m)(8m^2)$$

$$\mathcal{W} = \gamma \forall = \left(9.80 \frac{kN}{m^3}\right)(4\pi\ m^3)$$

Thus,

$$F_V = \left(9.80 \frac{kN}{m^3}\right)\left[32\ m^3 + 4\pi\ m^3\right] = \underline{\underline{437\ kN}}$$

(Note: Force of water on gate will be opposite in direction to that shown on figure.)

The direction of all differential forces acting on the curved surface is perpendicular to surface, and therefore, the resultant must pass through the intersection of all these forces which is at point A. <u>Yes.</u>

2.117

2.117 The 18-ft-long gate of Fig. P2.117 is a quarter circle and is hinged at *H*. Determine the horizontal force, *P*, required to hold the gate in place. Neglect friction at the hinge and the weight of the gate.

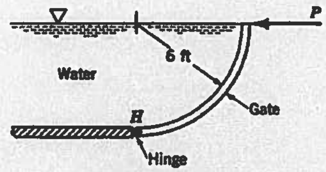
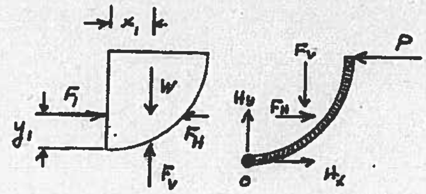


FIGURE P2.117



For equilibrium (from free-body-diagram of fluid mass),

$$\Sigma F_x = 0$$

so that

$$F_H = F_1 = \gamma h_{c1} A_1$$

$$= \left(62.4 \frac{lb}{ft^3}\right)\left(\frac{6 ft}{2}\right)(6 ft \times 18 ft) = 20{,}200 \, lb$$

Similarly,

$$\Sigma F_y = 0$$

so that

$$F_V = W = \gamma_{H_2O} \times (\text{volume of fluid}) = \left(62.4 \frac{lb}{ft^3}\right)\left[\frac{\pi}{4}(6ft)^2 \times 18 ft\right] = 31{,}800 \, lb$$

Also, $$x_1 = \frac{4(6ft)}{3\pi} = \frac{8}{\pi} \, ft \qquad (\text{see Fig. } 2.18e)$$

and $$y_1 = \frac{6ft}{3} = 2 \, ft$$

For equilibrium (from free-body-diagram of gate)

$$\Sigma M_0 = 0$$

so that

$$P(6ft) = F_H(y_1) + F_V(x_1)$$

or

$$P = \frac{(20{,}200 \, lb)(2 ft) + (31{,}800 \, lb)(\frac{8}{\pi} ft)}{6 \, ft} = \underline{\underline{20{,}200 \, lb}}$$

2.119

2.119 A tank wall has the shape shown in Fig. P2.119 Determine the horizontal and vertical components of the force of the water on a 4-ft length of the curved section AB.

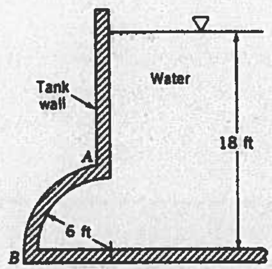
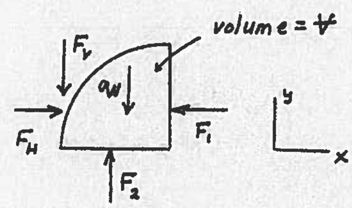


FIGURE P2.119

$$F_1 = \gamma h_{c1} A_1$$
$$= \left(62.4 \frac{lb}{ft^3}\right)(15\,ft)(6\,ft \times 4\,ft)$$
$$= 22{,}500\ lb$$
$$F_2 = \gamma h_{c2} A_2$$
$$= \left(62.4 \frac{lb}{ft^3}\right)(18\,ft)(6\,ft \times 4\,ft)$$
$$= 27{,}000\ lb$$
$$\mathcal{W} = \gamma \forall = \left(62.4 \frac{lb}{ft^3}\right)\left(\frac{1}{4}\right)(\pi)(6\,ft)^2(4\,ft)$$
$$= 7060\ lb$$



For equilibrium,

$$\Sigma F_x = 0$$

so that

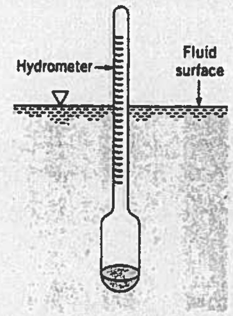
$$F_H = F_1 = \underline{\underline{22{,}500\ lb \leftarrow \text{ on tank}}}$$

and

$$F_V = F_2 - \mathcal{W} = 27{,}000\ lb - 7060\ lb = \underline{\underline{19{,}900\ lb \uparrow \text{ on tank}}}$$

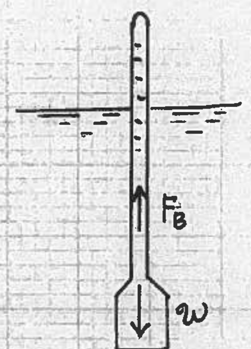
2.145

2.145 When a hydrometer (see Fig. P2.145 and Video V2.8) having a stem diameter of 0.30 in. is placed in water, the stem protrudes 3.15 in. above the water surface. If the water is replaced with a liquid having a specific gravity of 1.10, how much of the stem would protrude above the liquid surface? The hydrometer weighs 0.042 lb.



■ FIGURE P2.145

When the hydrometer is floating its weight, $\mathcal{W}$, is balanced by the buoyant force, F_B. For equilibrium,



$$\sum F_{vertical} = 0$$

Thus, for water

$$F_B = \mathcal{W}$$

$$(\gamma_{H_2O}) \forall_1 = \mathcal{W} \qquad (1)$$

where $\forall_1$ is the submerged volume. With the new liquid

$$(SG)(\gamma_{H_2O}) \forall_2 = \mathcal{W} \qquad (2)$$

Combining Eqs. (1) and (2) with $\mathcal{W}$ constant

$$(\gamma_{H_2O}) \forall_1 = (SG)(\gamma_{H_2O}) \forall_2$$

and

$$\forall_2 = \frac{\forall_1}{SG} \qquad (3)$$

(con't)

2.145 (Con't)

From Eq. (1)

$$\forall_1 = \frac{\mathcal{W}}{\gamma_{H_2O}} = \frac{0.042\ lb}{62.4\frac{lb}{ft^3}} = 6.73\times10^{-4}\ ft^3$$

so that from Eq. (3)

$$\forall_2 = \frac{6.73\times10^{-4}\ ft^3}{1.10} = 6.12\times10^{-4}\ ft^3$$

Thus, $\forall_1 - \forall_2 = (6.73-6.12)\times10^{-4}\ ft^3 = 0.61\times10^{-4}\ ft^3$

To obtain this difference the change in length, Δl, is

$$\left(\frac{\pi}{4}\right)(0.30\ in.)^2\,\Delta l = (0.61\times10^{-4}\ ft^3)\left(1728\ \frac{in.^3}{ft^3}\right)$$

$$\Delta l = 1.49\ in.$$

With the new liquid the stem would protrude

$$3.15\ in. + 1.49\ in. = \underline{\underline{4.64\ in.}}\ \text{above the surface}$$

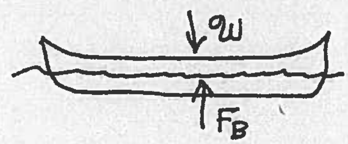
2.147

2.147 (See Fluids in the News article titled "Concrete canoe," Section 2.11.1.) How much extra water does a 147-lb concrete canoe displace compared to an ultralightweight 38-lb Kevlar canoe of the same size carrying the same load?

For equilibrium,

$$\sum F_{vertical} = 0$$

and $\mathcal{W} = F_B = \gamma_{H_2O} \forall$ and $\forall$ is displaced volume.



For concrete canoe,

$$147 \text{ lb} = \left(62.4 \frac{\text{lb}}{\text{ft}^3}\right) \forall_c$$

$$\forall_c = 2.36 \text{ ft}^3$$

For Kevlar canoe,

$$38 \text{ lb} = \left(62.4 \frac{\text{lb}}{\text{ft}^3}\right) \forall_k$$

$$\forall_k = 0.609 \text{ ft}^3$$

Extra water displacement $= 2.36 \text{ ft}^3 - 0.609 \text{ ft}^3$

$= \underline{\underline{1.75 \text{ ft}^3}}$