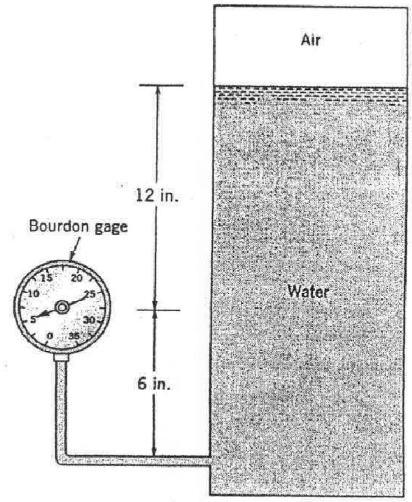
2.27

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

$$p = \gamma h + p_o$$

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

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

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

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).

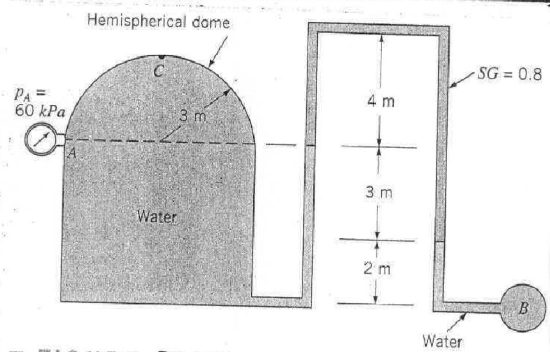


FIGURE P2.39

(a)

$$p_A + (SG)(\gamma_{H_2O})(3\,m) + \gamma_{H_2O}(2\,m) = p_B$$

$$p_B = 60\,kPa + (0.8)(9.81 \times 10^3 \tfrac{N}{m^3})(3\,m) + (9.80 \times 10^3 \tfrac{N}{m^3})(2\,m)$$

$$= \underline{\underline{103\,kPa}}$$

(b)

$$p_C = p_A - \gamma_{H_2O}(3\,m)$$

$$= 60\,kPa - (9.80 \times 10^3 \tfrac{N}{m^3})(3\,m)$$

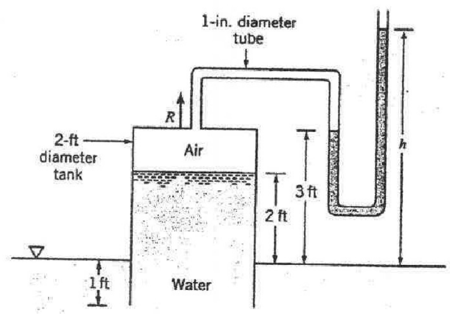
$$= 30.6 \times 10^3 \tfrac{N}{m^2}$$

$$h = \frac{p_C}{\gamma_{Hg}} = \frac{30.6 \times 10^3 \frac{N}{m^2}}{133 \times 10^3 \frac{N}{m^3}} = 0.230\,m$$

$$= 0.230\,m \left(\frac{10^3\,mm}{m}\right) = \underline{\underline{230\,mm}}$$

2.41

2.41 An inverted open tank is held in place by a force R as shown in Fig. P2.41. If the specific gravity of the manometer fluid is 2.5, determine the value of h.



■ FIGURE P2.41

$$\gamma_{gf}(h - 3\,ft) + \gamma_{H_2O}(2\,ft) = 0$$

$$h = 3\,ft - \frac{\gamma_{H_2O}(2\,ft)}{(SG)\,\gamma_{H_2O}}$$

$$= 3\,ft - \frac{2\,ft}{2.5}$$

$$= \underline{2.20\,ft}$$

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?

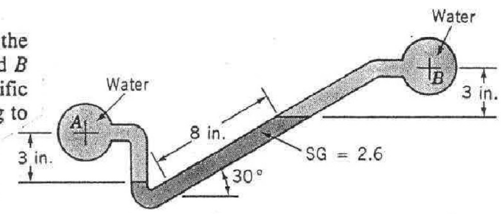


FIGURE P2.43

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

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

Thus,

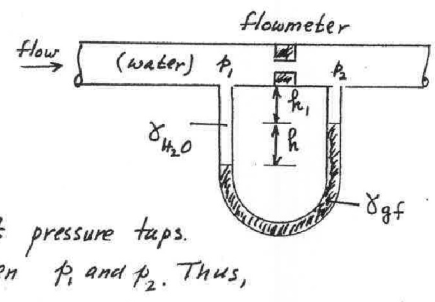
$$p_B = p_A - \gamma_{gf}\left(\tfrac{8}{12}\,ft\right)\sin 30°$$

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

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

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

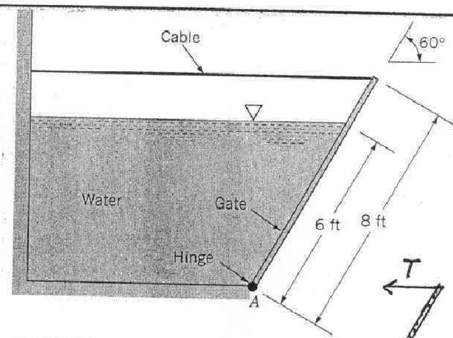
$$h = \frac{p_1 - p_2}{\gamma_{gf} - \gamma_{H_2O}} = \frac{\left(0.5\,\frac{lb}{in.^2}\right)\left(144\,\frac{in.^2}{ft^2}\right)}{112\,\frac{lb}{ft^3} - 62.4\,\frac{lb}{ft^3}}$$

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

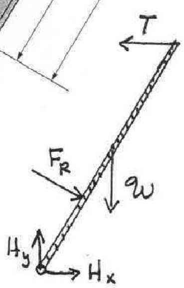
21 bi

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



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

Thus,

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

$$= 3890\ lb$$

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,

$$\sum M_H = 0$$

and

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

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

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

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.

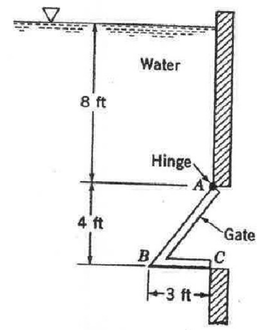


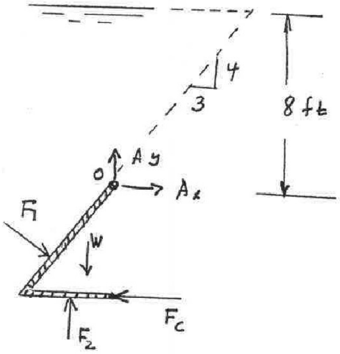
FIGURE P2.95

$F_1 = \gamma h_{c1} A_1$ 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 $F_1\left(y_1 - \dfrac{8\,ft}{\frac{4}{5}}\right) + W(1\,ft) - F_2(\tfrac{1}{2})(3\,ft) - F_c(4\,ft)$

so that

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

2.97

2.97 The massless, 4-ft-wide gate shown in Fig. P2.97 pivots about the frictionless hinge O. It is held in place by the 2000 lb counterweight, W. Determine the water depth, h.

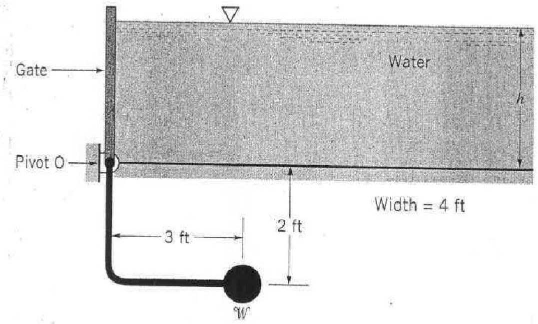
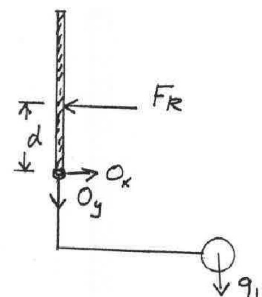


FIGURE P2.97

$$F_R = \gamma h_c A \quad \text{where} \quad h_c = \frac{h}{2}$$



Thus,

$$F_R = \gamma_{H_2O} \frac{h}{2}(h \times b)$$

$$= \gamma_{H_2O} \frac{h^2}{2}(4 ft)$$

$b = 4 ft$

To locate F_R,

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

$$= \frac{2}{3}h$$

For equilibrium,

$$\sum M_o = 0$$

$$F_R\, d = W(3ft) \quad \text{where} \quad d = h - y_R = \frac{h}{3}$$

so that

$$\frac{h}{3} = \frac{(2000\, lb)(3ft)}{(\gamma_{H_2O})(\frac{h^2}{2})(4 ft)}$$

Thus,

$$h^3 = \frac{(3)(2000\, lb)(3ft)}{(62.4 \frac{lb}{ft^3})(\frac{1}{2})(4ft)}$$

$$h = \underline{\underline{5.24 ft}}$$

2.122

2.122 The homogeneous gate shown in Fig. P2.122 consists of one quarter of a circular cylinder and is used to maintain a water depth of 4 m. That is, when the water depth exceeds 4 m, the gate opens slightly and lets the water flow under it. Determine the weight of the gate per meter of length.

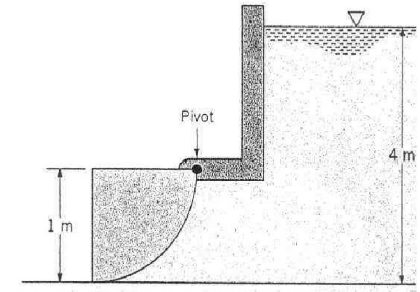
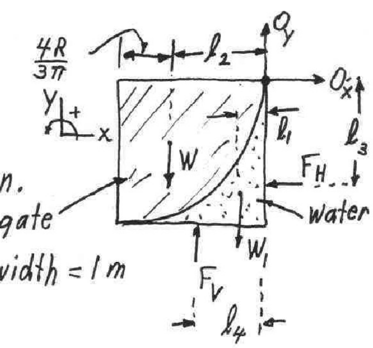


FIGURE P2.122



Consider the free body diagram of the gate and a portion of the water as shown.

gate width = 1 m

$\sum M_0 = 0$, or

(1) $\ell_2 W + \ell_1 W_1 - F_H \ell_3 - F_V \ell_4 = 0$, where

(2) $F_H = \gamma h_c A = 9.8\times10^3 \frac{N}{m^3}(3.5\,m)(1\,m)(1\,m) = 34.3\,kN$

since for the vertical side, $h_c = 4m - 0.5m = 3.5m$

Also,

(3) $F_V = \gamma h_c A = 9.8\times10^3 \frac{N}{m^3}(4m)(1m)(1m) = 39.2\,kN$

Also,

(4) $W_1 = \gamma(1m)^3 - \gamma(\frac{\pi}{4}(1m)^2)(1m) = 9.8\times10^3\frac{N}{m^3}[1-\frac{\pi}{4}]m^3 = 2.10\,kN$

(5) Now, $\ell_4 = 0.5m$ and

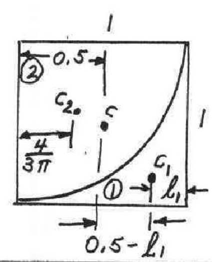
(6) $\ell_3 = 0.5m + (y_R - y_c) = 0.5m + \frac{I_{xc}}{y_c A} = 0.5m + \frac{\frac{1}{12}(1m)(1m)^3}{3.5m(1m)(1m)} = 0.524m$

(7) and $\ell_2 = 1m - \frac{4R}{3\pi} = 1 - \frac{4(1m)}{3\pi} = 0.576m$

To determine ℓ_1, consider a unit square that consits of a quarter circle and the remainder as shown in the figure. The centroids of areas ① and ② are as indicated.

Thus,

$(0.5 - \frac{4}{3\pi})A_2 = (0.5 - \ell_1)A_1$



(con't)

68 bi

2.122 (con't)

so that with $A_2 = \frac{\pi}{4}(1)^2 = \frac{\pi}{4}$ and $A_1 = 1 - \frac{\pi}{4}$ this gives

$$\left(0.5 - \frac{4}{3\pi}\right)\frac{\pi}{4} = (0.5 - \ell_1)\left(1 - \frac{\pi}{4}\right)$$

or

(8) $\ell_1 = 0.223\ m$

Hence, by combining Eqs (1) through (8):

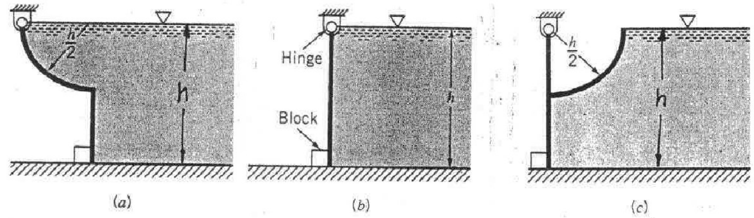
$$(0.576m)W + (0.223m)(2.10\ kN) - (34.3\ kN)(0.524m) - (39.2\ kN)(0.5m) = 0$$

or

$$W = \underline{\underline{64.4\ kN}}$$

2.131

2.131 Three gates of negligible weight are used to hold back water in a channel of width b as shown in Fig. P2.131 The force of the gate against the block for gate (b) is R. Determine (in terms of R) the force against the blocks for the other two gates.



■ FIGURE P2.131

For case (b)

$$F_R = \gamma h_c A = \gamma\left(\frac{h}{2}\right)(h \times b) = \frac{\gamma h^2 b}{2}$$

and $y_R = \frac{2}{3}h$

Thus,

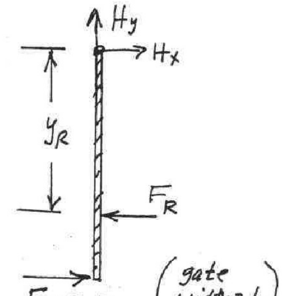
$$\Sigma M_H = 0$$

so that

$$hR = \left(\frac{2}{3}h\right)F_R$$

$$hR = \left(\frac{2}{3}h\right)\left(\frac{\gamma h^2 b}{2}\right)$$

$$R = \frac{\gamma h^2 b}{3} \qquad (1)$$



For case (a) on free-body-diagram shown

$F_R = \frac{\gamma h^2 b}{2}$ (from above) and

$y_R = \frac{2}{3}h$

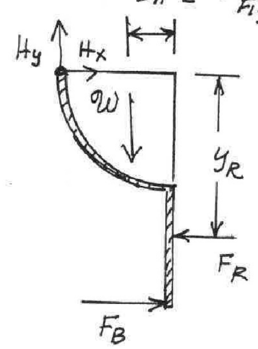
and

$$\mathcal{W} = \gamma \times \text{Vol}$$

$$= \gamma\left[\frac{\pi\left(\frac{h}{2}\right)^2}{4}(b)\right]$$

$$= \frac{\pi \gamma h^2 b}{16}$$

$\frac{4}{3\pi}\frac{h}{2}$ (See Fig. 2.18)



Thus, $\Sigma M_H = 0$

so that

$$\mathcal{W}\left(\frac{h}{2} - \frac{4h}{6\pi}\right) + F_R\left(\frac{2}{3}h\right) = F_B\, h$$

and

$$\frac{\pi \gamma h^2 b}{16}\left(\frac{h}{2} - \frac{4h}{6\pi}\right) + \frac{\gamma h^2 b}{2}\left(\frac{2}{3}h\right) = F_B\, h$$

(con't)

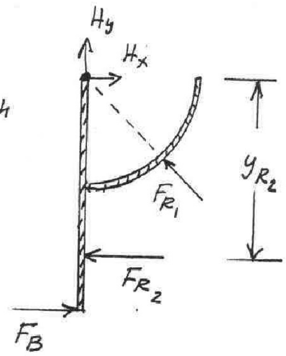
2.131 (con't)

It follows that

$$F_B = \gamma h^2 b\,(0.390)$$

From Eq. (1) $\gamma h^2 b = 3R$, thus

$$F_B = \underline{\underline{1.17R}}$$



For case (c), for the free-body-diagram shown, the force F_{R_1} on the curved section passes through the hinge and therefore does not contribute to the moment around H. On bottom part of gate

$$F_{R_2} = \gamma h_c A = \gamma\left(\frac{3h}{4}\right)\left(\frac{h}{2}\times b\right) = \frac{3}{8}\gamma h^2 b$$

and

$$y_{R_2} = \frac{I_{xc}}{y_c A} + y_c = \frac{\frac{1}{12}(b)\left(\frac{h}{2}\right)^3}{\left(\frac{3h}{4}\right)\left(\frac{h}{2}\times b\right)} + \frac{3h}{4}$$

$$= \frac{28}{36}h$$

Thus, $\Sigma M_H = 0$

so that

$$F_{R_2}\left(\frac{28}{36}h\right) = F_B\, h$$

or

$$F_B = \left(\frac{3}{8}\gamma h^2 b\right)\left(\frac{28}{36}\right) = \frac{7}{24}\gamma h^2 b$$

From Eq. (1) $\gamma h^2 b = 3R$, thus

$$F_B = \frac{7}{8}R = \underline{\underline{0.875R}}$$

2.143

2.143 A 1-m-diameter cylindrical mass, M, is connected to a 2-m-wide rectangular gate as shown in Fig. P2.143. The gate is to open when the water level, h, drops below 2.5 m. Determine the required value for M. Neglect friction at the gate hinge and the pulley.

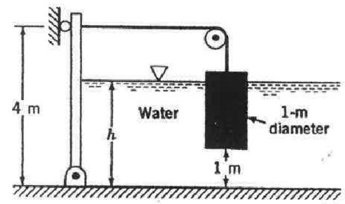
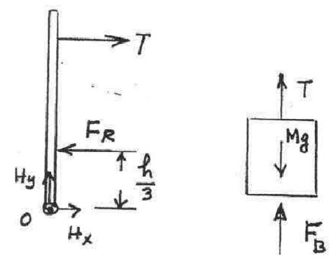


FIGURE P2.143

$$F_R = \gamma h_c A$$
$$= \gamma \left(\frac{h}{2}\right) h\,(2)$$
$$= \gamma h^2$$



where all lengths are in m.

For equilibrium,

$$\sum M_O = 0$$

so that

$$4T = \left(\frac{h}{3}\right) F_R = \gamma \frac{h^3}{3}$$

and

$$T = \frac{\gamma h^3}{12}$$

For the cylindrical mass $\sum F_{vertical} = 0$ and

$$T = Mg - F_B = Mg - \gamma \forall_{mass}$$

Thus,

$$M = \frac{T + \gamma \forall_{mass}}{g} = \frac{\frac{\gamma h^3}{12} + \gamma \left(\frac{\pi}{4}\right)(1)^2 (h-1)}{g}$$

and for $h = 2.5\,m$

$$M = \frac{\left(9.80 \times 10^3 \frac{N}{m^3}\right)\left[\frac{(2.5\,m)^3}{12} + \frac{\pi}{4}(1\,m)^2 (2.5\,m - 1.0\,m)\right]}{9.81 \frac{m}{s^2}}$$

$$= \underline{\underline{2480\ kg}}$$

2.156

2.156 The open U-tube of Fig. P2.156 is partially filled with a liquid. When this device is accelerated with a horizontal acceleration, a, a differential reading, h, develops between the manometer legs which are spaced a distance ℓ apart. Determine the relationship between a, ℓ, and h.

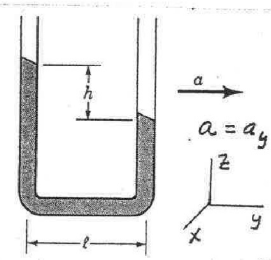


FIGURE P2.156

$$\frac{dz}{dy} = -\frac{a_y}{g + a_z} \qquad \text{(Eq. 2.28)}$$

Since, $\frac{dz}{dy} = -\frac{h}{\ell}$ and $a_z = 0$

then $-\frac{h}{\ell} = -\frac{a}{g+0}$

or

$$\underline{\underline{h = \frac{a\ell}{g}}}$$

2.158

2.158 The U-tube of Fig. P2.158 contains mercury and rotates about the off-center axis *a–a*. At rest, the depth of mercury in each leg is 150 mm as illustrated. Determine the angular velocity for which the difference in heights between the two legs is 75 mm.

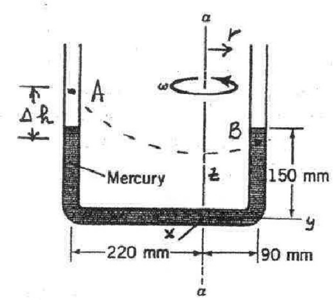


FIGURE P2.158

The equation of the free surface passing through A and B is

$$z = \frac{\omega^2 r^2}{2g} + \text{constant} \qquad (Eq. 2.32)$$

Thus,

$$z_A - z_B = \Delta h = \frac{\omega^2}{2g}\left(r_A^2 - r_B^2\right)$$

so that

$$\omega = \sqrt{\frac{2g(\Delta h)}{r_A^2 - r_B^2}}$$

$$= \sqrt{\frac{2\left(9.81\,\frac{m}{s^2}\right)(0.075\,m)}{(0.220\,m)^2 - (0.090\,m)^2}} = \underline{\underline{6.04\,\frac{rad}{s}}}$$