AKM204E Fluid Mechanics
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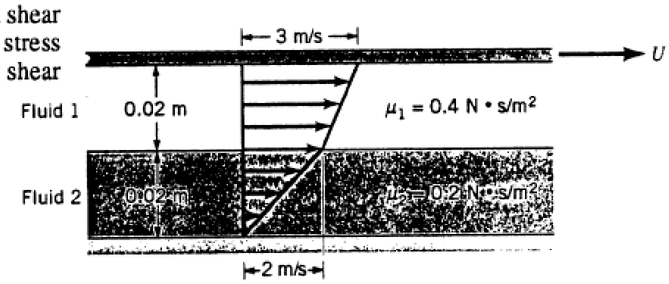
HOMEWORK 1 ***S O L U T I O N S***

1.54

1.54 As shown in **Video V1.2**, the "no slip" condition means that a fluid "sticks" to a solid surface. This is true for both fixed and moving surfaces. Let two layers of fluid be dragged along by the motion of an upper plate as shown in Fig. P1.54. The bottom plate is stationary. The top fluid puts a shear stress on the upper plate, and the lower fluid puts a shear stress on the botton plate. Determine the ratio of these two shear stresses.



■ **FIGURE P1.54**

For fluid 1

$$\tau_1 = \mu_1 \left(\frac{du}{dy}\right)_{\text{top surface}} = \left(0.4\,\frac{N\cdot s}{m^2}\right)\left(\frac{3\,\frac{m}{s} - 2\,\frac{m}{s}}{0.02\,m}\right) = 20\,\frac{N}{m^2}$$

For fluid 2

$$\tau_2 = \mu_2 \left(\frac{du}{dy}\right)_{\text{bottom surface}} = \left(0.2\,\frac{N\cdot s}{m^2}\right)\left(\frac{2\,\frac{m}{s}}{0.02\,m}\right) = 20\,\frac{N}{m^2}$$

Thus,

$$\frac{\tau_{\text{top surface}}}{\tau_{\text{bottom surface}}} = \frac{20\,\frac{N}{m^2}}{20\,\frac{N}{m^2}} = \underline{\underline{1}}$$

2.31

2.31 The mercury manometer of Fig. P2.3 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.

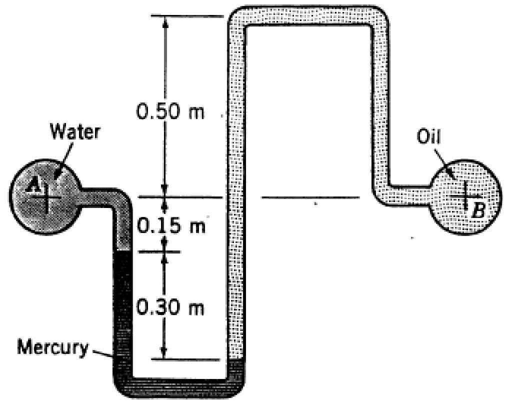


FIGURE P2.31

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

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

Thus,

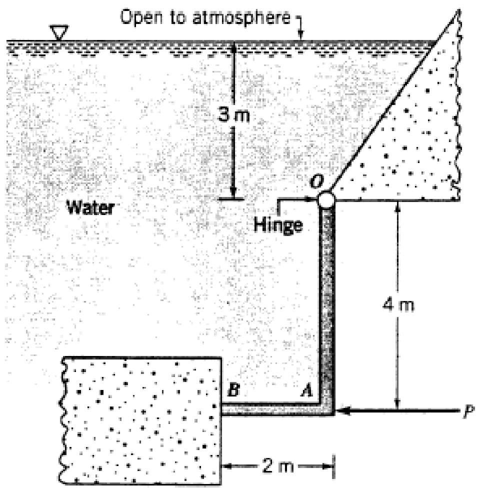
$$p_B = -\gamma_{Hg}(0.030\,m) - \gamma_{oil}(0.45\,m) + \gamma_{Hg}(0.3\,m) + \gamma_{H_2O}(0.15\,m)$$

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

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

2.58

2.58 The rigid gate, OAB, of Fig. P2.58 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 P2.58

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

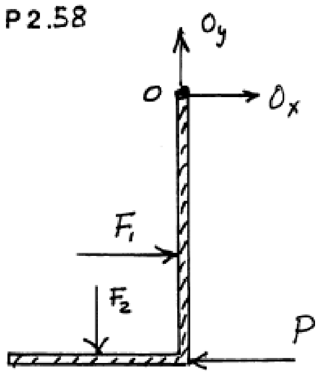
Thus,

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

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

so that

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



To locate F_1,

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

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

$$\sum M_O = 0$$

and

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

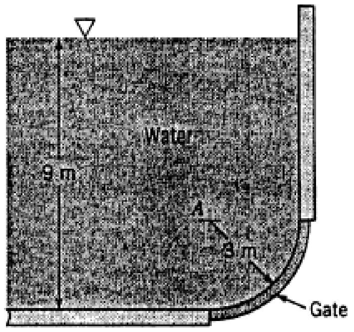
so that

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

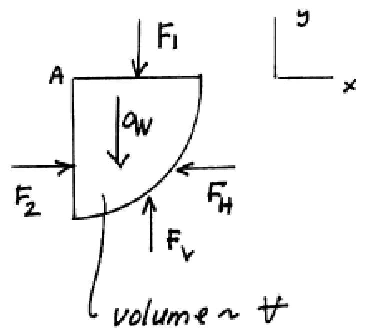
$$= \underline{\underline{436\ kN}}$$

2.70

2.70 A 4-m-long curved gate is located in the side of a reservoir containing water as shown in Fig. P2.70. 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 P2.70



and
$$\forall = \frac{\pi (3\,m)^2}{4} \times 4\,m = 9\pi\ m^3$$

For equilibrium,

$$\Sigma F_x = 0$$

or

$$F_H = F_2 = \gamma h_{c2} A_2 = \gamma (6m + 1.5m)(3m \times 4m)$$

so that

$$F_H = \left(9.80\,\frac{kN}{m^3}\right)(7.5m)(12\,m^2) = \underline{\underline{882\ kN}}$$

Similarly,

$$\Sigma F_y = 0$$

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

$$F_1 = [\gamma(6m)](3m \times 4m) = \left(9.80\,\frac{kN}{m^3}\right)(6m)(12\,m^2)$$

$$\mathcal{W} = \gamma \forall = \left(9.80\,\frac{kN}{m^3}\right)(9\pi\,m^3)$$

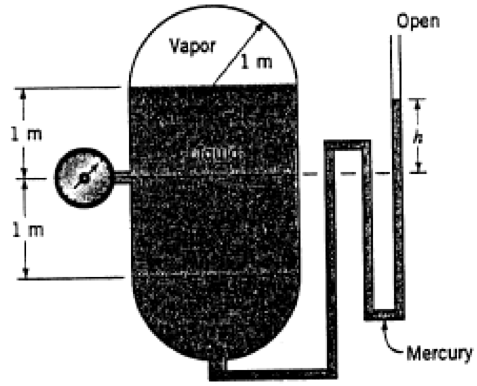
Thus,
$$F_V = \left(9.80\,\frac{kN}{m^3}\right)\left[72\ m^3 + 9\pi\ m^3\right] = \underline{\underline{983\ kN}}$$

(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>

2.35

2.35 The cyclindrical tank with hemispherical ends shown in Fig. P2.35 contains a volatile liquid and its vapor. The liquid density is 800 kg/m^3, and its vapor density is negligible. The pressure in the vapor is 120 kPa (abs), and the atmospheric pressure is 101 kPa (abs). Determine: (a) the gage pressure reading on the pressure gage; and (b) the height, h, of the mercury manometer.



■ FIGURE P2.35

(a) Let γ_l = sp. wt. of liquid $= \left(800 \frac{kg}{m^3}\right)\left(9.81 \frac{m}{s^2}\right) = 7850 \frac{N}{m^3}$

and

p_{vapor} (gage) = 120 kPa (abs) − 101 kPa (abs) = 19 kPa

Thus,

$$p_{gage} = p_{vapor} + \gamma_l\,(1\,m)$$
$$= 19 \times 10^3 \frac{N}{m^2} + \left(7850 \frac{N}{m^3}\right)(1\,m)$$
$$= \underline{\underline{26.9\ kPa}}$$

(b) $p_{vapor}\,(gage) + \gamma_l\,(1\,m) - \gamma_{Hg}\,(h) = 0$

$$19 \times 10^3 \frac{N}{m^2} + \left(7850 \frac{N}{m^3}\right)(1\,m) - \left(133 \times 10^3 \frac{N}{m^3}\right)(h) = 0$$

$$h = \underline{\underline{0.202\ m}}$$

2.97

2.97 The open U-tube of Fig. P2.97 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.

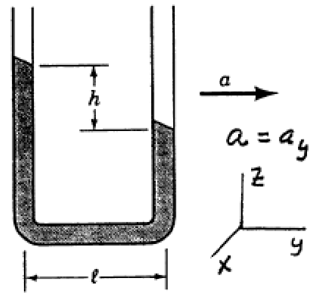


FIGURE P2.97

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

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

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

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