2.3

2.3 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/m^3) 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?

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

$$\gamma_u = \frac{p_{bottom} - (\gamma_{oil})(5m)}{1.5\,m} = \frac{65\times10^3\frac{N}{m^2} - \left(8.5\times10^3\frac{N}{m^3}\right)(5m)}{1.5\,m}$$

$$= 15\times10^3\,\frac{N}{m^3}$$

$$SG = \frac{\gamma_u}{\gamma_{H_2O}\,@\,4^\circ C} = \frac{15\times10^3\,\frac{N}{m^3}}{9.81\times10^3\,\frac{N}{m^3}} = \underline{\underline{1.53}}$$

2.4

2.4 The two open tanks shown in Fig. P2.4 have the same bottom area, *A*, but different shapes. When the depth, *h*, of a liquid in the two tanks is the same, the pressure on the bottom of the two tanks will be the same in accordance with Eq. 2.7. However, the weight of the liquid in each of the tanks is different. How do you account for this apparent paradox?

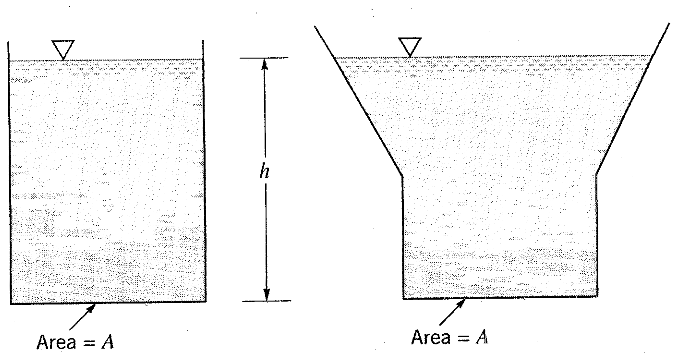
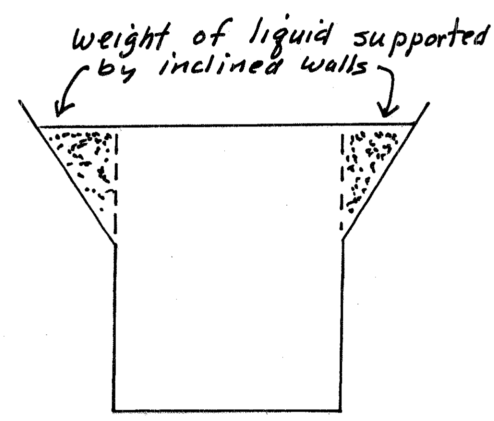


FIGURE P2.4



For the tank with the inclined walls, the pressure on the bottom is due to the weight of the liquid in the column directly above the bottom as shown by the dashed lines in the figure. This is the same weight as that for the tank with the straight sides. Thus, the pressure on the bottom of the two tanks is the same. The additional weight in the tank with the inclined walls is supported by the inclined walls, as illustrated in the figure.

2.12

2.12 The basic elements of a hydraulic press are shown in Fig. P2.12. The plunger has an area of 1 in.^{2}, and a force, F_1, can be applied to the plunger through a lever mechanism having a mechanical advantage of 8 to 1. If the large piston has an area of 150 in.^{2}, what load, F_2, can be raised by a force of 30 lb applied to the lever? Neglect the hydrostatic pressure variation.

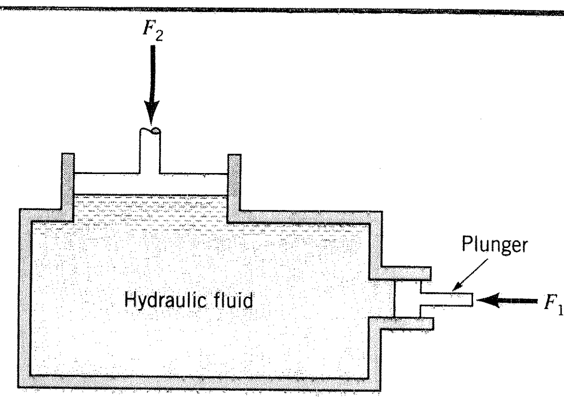


FIGURE P2.12

A force of 30 lb applied to the lever results in a plunger force, F_1, of $F_1 = (8)(30) = 240\ lb$.
Since $F_1 = pA_1$ and $F_2 = pA_2$ where p is the pressure and A_1 and A_2 are the areas of the plunger and piston, respectively. Since p is constant throughout the chamber,

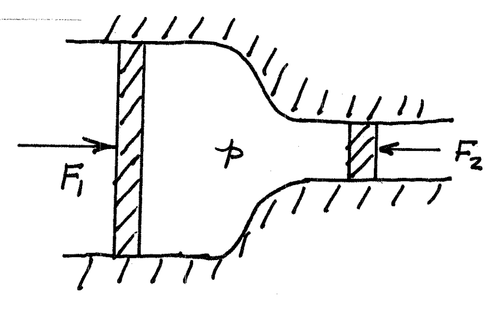
$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

so that

$$F_2 = \frac{A_2}{A_1} F_1 = \left(\frac{150\ in.^2}{1\ in.^2}\right)(240\ lb) = \underline{\underline{36{,}000\ lb}}$$

2.13

2.13 A 0.3-m-diameter pipe is connected to a 0.02-m-diameter pipe and both are rigidly held in place. Both pipes are horizontal with pistons at each end. If the space between the pistons is filled with water, what force will have to be applied to the larger piston to balance a force of 80 N applied to the smaller piston? Neglect friction.



$F_1 = pA_1$

$F_2 = pA_2$

Thus,

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

or

$$F_1 = \frac{A_1}{A_2} F_2 = \frac{(0.3\ m)^2}{(0.02\ m)^2}(80\ N) = \underline{\underline{18{,}000\ N}}$$

2.38

2.38 An air-filled, hemispherical shell is attached to the ocean floor at a depth of 10 m as shown in Fig. P2.38. A mercury barometer located inside the shell reads 765 mm Hg, and a mercury U-tube manometer designed to give the outside water pressure indicates a differential reading of 735 mm Hg as illustrated. Based on these data what is the atmospheric pressure at the ocean surface?

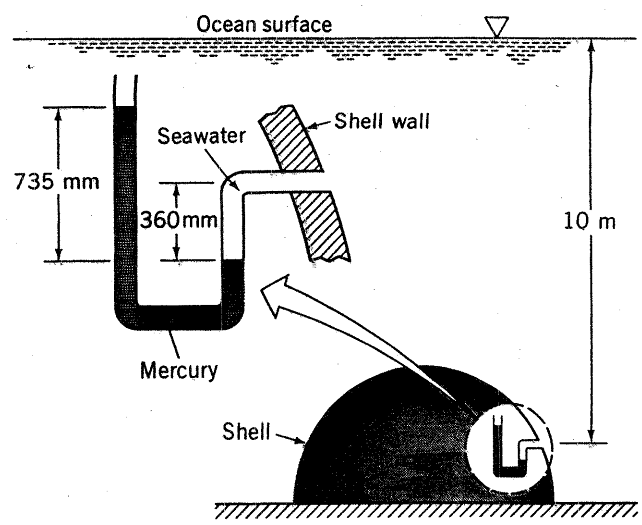


FIGURE P2.38

Let: p_a ~ absolute air pressure inside shell $= \gamma_{Hg}\,(0.765\,m)$

p_{atm} ~ surface atmospheric pressure

γ_{sw} ~ specific weight of seawater

Thus, manometer equation can be written as

$$p_{atm} + \gamma_{sw}\,(10\,m) + \gamma_{sw}\,(0.360\,m) - \gamma_{Hg}\,(0.735\,m) = p_a$$

so that

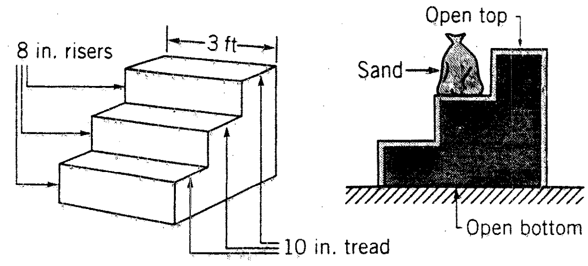
$$p_{atm} = p_a - \gamma_{sw}\,(10.36\,m) + \gamma_{Hg}\,(0.735\,m)$$

$$= \left(133\,\frac{kN}{m^3}\right)(0.765\,m) - \left(10.1\,\frac{kN}{m^3}\right)(10.36\,m) + \left(133\,\frac{kN}{m^3}\right)(0.735\,m)$$

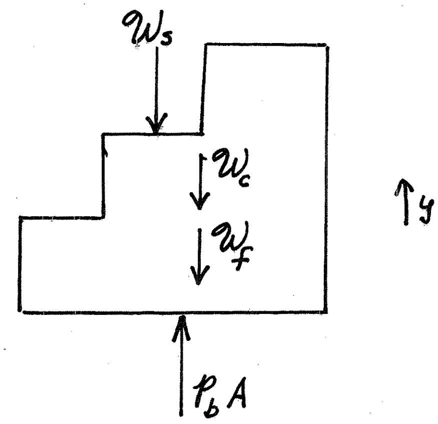
$$= \underline{\underline{94.9\,kPa}}$$

2.48

2.48 Concrete is poured into the forms as shown in Fig. P2.48 to produce a set of steps. Determine the weight of the sandbag needed to keep the bottomless forms from lifting off the ground. The weight of the forms is 85 lb, and the specific weight of the concrete is 150 lb/ft^3.



■ FIGURE P2.48



From the free-body-diagram

$(+\downarrow)\ \Sigma F_y = 0$

$$\mathcal{W}_s + \mathcal{W}_c + \mathcal{W}_f - p_b A = 0 \qquad (1)$$

Where:

$\mathcal{W}_s$ = weight of sandbag

$\mathcal{W}_c$ = weight of concrete

$\mathcal{W}_f$ = weight of forms

p_b = pressure along bottom surface due to concrete

A = area of bottom surface

From the data given:

$$\mathcal{W}_c = \left(150\ \tfrac{lb}{ft^3}\right)(\text{Vol. concrete})$$

$$= \left(150\ \tfrac{lb}{ft^3}\right)(3\,ft)\ \frac{[(10\,in.)(24\,in.) + (10\,in.)(16\,in.) + (10\,in.)(8\,in.)]}{144\ \frac{in.^2}{ft^2}}$$

$$= 1500\ lb$$

$$\mathcal{W}_f = 85\ lb$$

$$p_A = \left(150\ \tfrac{lb}{ft^3}\right)\left(\tfrac{24}{12}\,ft\right) = 300\ \tfrac{lb}{ft^2}$$

$$A = \left(\tfrac{30}{12}\,ft\right)(3\,ft) = 7.5\,ft^2$$

Thus, from Eq. (1)

$$\mathcal{W}_s = \left(300\ \tfrac{lb}{ft^2}\right)(7.5\,ft^2) - 1500\ lb - 85\ lb$$

$$= \underline{\underline{665\ lb}}$$

2.59

2.59 The massless, 4-ft-wide gate shown in Fig. P2.59 pivots about the frictionless hinge O. It is held in place by the 2000 lb counterweight, W. Determine the water depth, h.

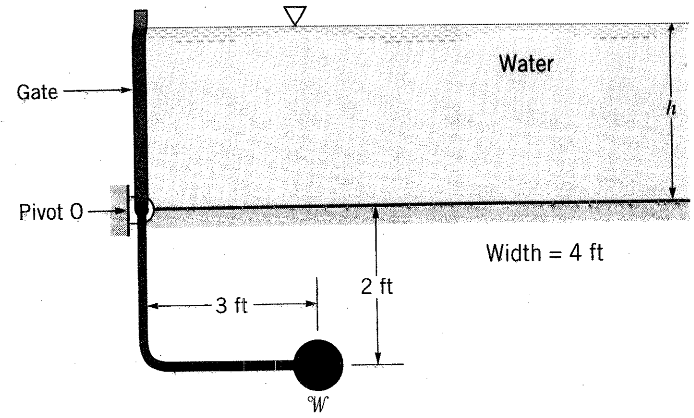


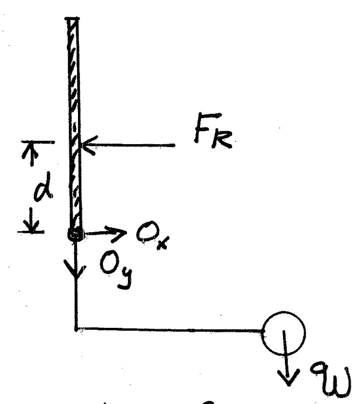
FIGURE P2.59

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

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,

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

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

For equilibrium,

$$\sum M_O = 0$$

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

so that

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

Thus,

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

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

2.68

2.68 Dams can vary from very large structures with curved faces holding back water to great depths, as shown in Video V2.3, to relatively small structures with plane faces as shown in Fig. P2.68. Assume that the concrete dam shown in Fig. P2.68 weighs 23.6 kN/m³ and rests on a solid foundation. Determine the minimum coefficient of friction between the dam and the foundation required to keep the dam from sliding at the water depth shown. You do not need to consider possible uplift along the base. Base your analysis on a unit length of the dam.

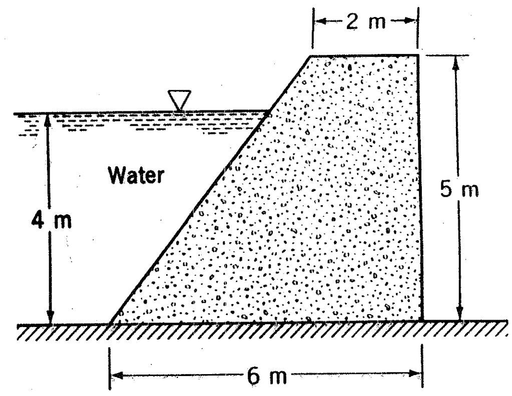
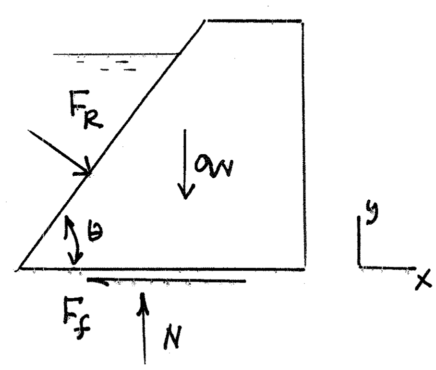


FIGURE P2.68



$F_R = \gamma h_c A$

where $A = \left(\frac{4\text{ m}}{\sin 51.3°}\right)(1 \quad)$

so that

$$F_R = \left(9.80\frac{\text{kN}}{\text{m}^3}\right)\left(\frac{4\text{ m}}{2}\right)\left(\frac{4\text{ m}}{\sin 51.3°}\right)(1\text{ m})$$
$$= 100\text{ kN}$$

$\tan\theta = \frac{5\text{ m}}{4\text{ m}}$

$\theta = 51.3°$

For equilibrium,

$\Sigma F_x = 0$

or

$F_R \sin 51.3° = F_f = \eta N$ where $\eta \sim$ coefficient of friction.

Also, $\Sigma F_y = 0$

so that

$N = \mathcal{W} + F_R \cos 51.3°$ where

$\mathcal{W} = (\gamma_{concrete})(\text{volume of concrete})$

Thus,

$$N = \left(23.6\frac{\text{kN}}{\text{m}^3}\right)(20\text{ m}^3) + (100\text{ kN})\cos 51.3° = 534\text{ kN}$$

and

$$\eta = \frac{F_R \sin 51.3°}{N} = \frac{(100\text{ kN})\sin 51.3°}{534\text{ kN}} = \underline{\underline{0.146}}$$