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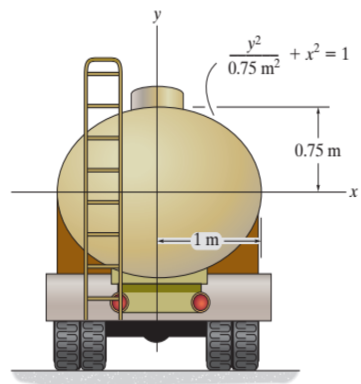
Tutorial 2

1- The tank truck is filled to its top with water. Determine the magnitude of the resultant force on the elliptical back plate of the tank, and the location of the center of pressure measured from the top of the tank. Solve the problem using the formula method.



SOLUTION

Using Table 2-1 for the area and moment of inertia about the centroidal $\bar{x}$ axis of the elliptical plate, we get

$$F = \rho_w g \bar{h} A = (1000\text{ kg/m}^3)(9.81\text{ m/s}^2)(0.75\text{ m})(\pi)(0.75\text{ m})(1\text{ m})$$
$$= 17.3\text{ kN} \qquad \textbf{Ans.}$$

The center of pressure is at

$$y_P = \frac{\bar{I}_x}{\bar{y}A} + \bar{y}$$
$$= \frac{\left[\frac{1}{4}\pi(1\text{ m})(0.75\text{ m})^3\right]}{(0.75\text{ m})\pi(1\text{ m})(0.75\text{ m})} + 0.75\text{ m}$$
$$= 0.9375\text{ m} = 0.938\text{ m} \qquad \textbf{Ans.}$$

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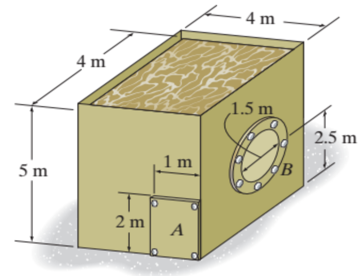
Unless otherwise stated, take the density of water to be $\rho_w = 1000\ \text{kg/m}^3$ and its specific weight to be $\gamma_w = 62.4\ \text{lb/ft}^3$. Also, assume all pressures are gage pressures.

2- Access plates on the industrial holding tank are bolted shut when the tank is filled with vegetable oil as shown. Determine the resultant force that this liquid exerts on plate B, and its location measured from the bottom of the tank. Use the formula method. $\rho_{ma} = 932\ \text{kg/m}^3$.



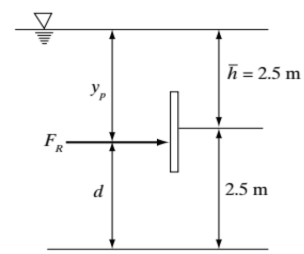
SOLUTION

Since the plate is circular in shape, it is convenient to compute the resultant force as follows

$$F_R = \gamma_{vo}\,\bar{h}A = \left(932\ \text{kg/m}^3\right)\left(9.81\ \text{m/s}^2\right)(2.5\ \text{m})\left[\pi(0.75\ \text{m})^2\right]$$
$$= 40.392\left(10^3\right)\ \text{N} = 40.4\ \text{kN} \qquad \textbf{Ans.}$$

The location of the center of pressure can be determined form

$$y_P = \frac{\bar{I}_x}{\bar{y}A} + \bar{y} = \frac{\pi\dfrac{(0.75\ \text{m})^4}{4}}{(2.5\ \text{m})(\pi)(0.75\ \text{m})^2} + 2.5\ \text{m}$$
$$= 2.556\ \text{m}$$



(a)

From the bottom of the tank, Fig. a,

$$d = 5\ \text{m} - y_P = 5\ \text{m} - 2.556\ \text{m} = 2.44\ \text{m} \qquad \textbf{Ans.}$$

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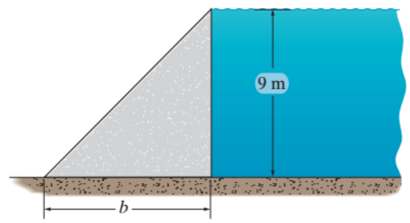
3- Determine the smallest base length b of the concrete gravity dam that will prevent the dam from overturning due to water pressure acting on the face of the dam. The density of concrete is $\rho_c = 2.4\ \mathrm{Mg/m^3}$. *Hint:* Work the problem using a 1-m width of the dam.



SOLUTION

If we consider the dam as having a width of $b = 1$ m, the intensity of the distributed load at the base of the dam is

$$w_b = \rho g h(b) = (1000\ \mathrm{kg/m^3})(9.81\ \mathrm{m/s^2})(9\ \mathrm{m})(1\ \mathrm{m})$$
$$= 88.29(10^3)\ \mathrm{N/m}$$

The resultant force of the triangular distributed load shown on the free-body diagram of the dam, Fig. *a*. is

$$F = \frac{1}{2} w_b h = \frac{1}{2}\left[88.29(10^3)\ \mathrm{N/m}\right](9\ \mathrm{m}) = 397.305(10^3)\ \mathrm{N}$$

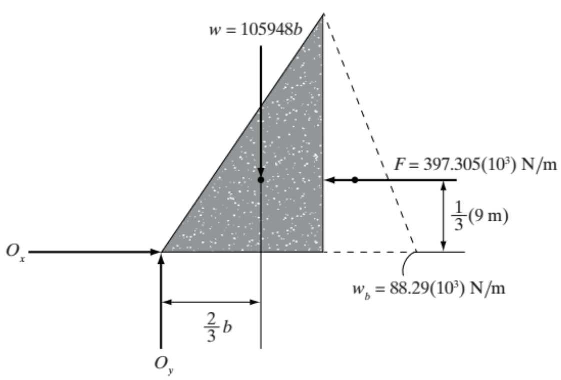
The weight of the dam is given by

$$W = \rho_C g \forall = \left[2.4(10^3)\ \mathrm{kg/m^3}\right](9.81\ \mathrm{m/s^2})\left[\frac{1}{2}(9\ \mathrm{m})(1\ \mathrm{m})b\right]$$
$$= 105\,948b$$

The dam will overturn about point O. Referring to the free-body diagram of the dam, Fig. *a*,

$$\circlearrowleft + \Sigma M_0 = 0; \qquad \left[397.305(10^3)\ \mathrm{N}\right]\left[\frac{1}{3}(9\ \mathrm{m})\right] - 105\,948b\left(\frac{2}{3}b\right) = 0$$

$$b = 4.108\ \mathrm{m} = 4.11\ \mathrm{m}$$ **Ans.**



(a)

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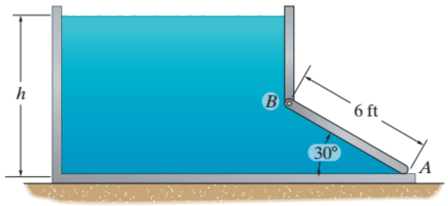
4- The uniform rectangular relief gate AB has a weight of 8000 lb and a width of 4 ft. Determine the minimum depth h of water within the canal needed to open it. The gate is pinned at B and rests on a rubber seal at A.



SOLUTION

Here $h_B = h - 6\sin 30° = (h-3)$ ft and $h_A = h$. Thus, the intensities of the distributed load at B and A are

$$w_B = \gamma_w h_B b = (62.4\ \text{lb/ft}^3)(h - 3\ \text{ft})(4\ \text{ft}) = (249.6h - 748.8)\ \text{lb/ft}$$

$$w_A = \gamma_w h_A b = (62.4\ \text{lb/ft}^3)(h)(4\ \text{ft}) = (249.6h)\ \text{lb/ft}.$$

Thus,

$$(F_p)_1 = \left[(249.6h - 748.8\ \text{lb/ft})\right](6\ \text{ft}) = (1497.6h - 4492.8)\ \text{lb}$$

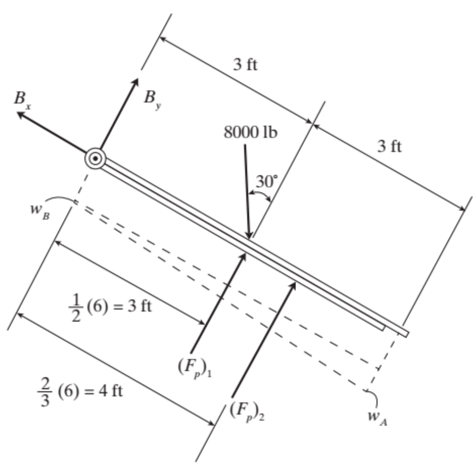
$$(F_p)_2 = \frac{1}{2}\left[(249.6h\ \text{lb/ft}) - (249.6h - 748.8\ \text{lb/ft})\right](6\ \text{ft}) = 2246.4\ \text{lb}$$

If it is required that the gate is about to open, then the normal reaction at A is equal to zero. Write the moment equation of equilibrium about B, referring to Fig. *a*,

$$\circlearrowleft + \Sigma M_B = 0;\ \left[(1497.6h - 4492.8\ \text{lb})\right](3\ \text{ft}) + (2246.4\ \text{lb})(4\ \text{ft})$$

$$-(8000\ \text{lb})\cos 30°(3\ \text{ft}) = 0$$

$$h = 5.626\ \text{ft} = 5.63\ \text{ft}$$ **Ans.**



(a)