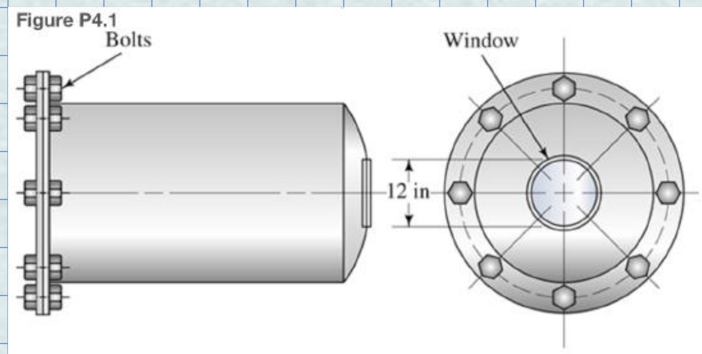
HW 2.1

Group 2: Sanchez, Perkins, Ashley, Wells, Watts

4.2 The flat left end of the tank shown in **Fig. P4.1** is secured with a bolted flange. If the inside diameter of the tank is 30 in and the internal pressure is raised to $+23.6$ psig, calculate the total force that must be resisted by the bolts in the flange.

Figure P4.1



$F = PA$ where $A = \frac{\pi(30\,in)^2}{4} = 706.9\ in^2$

$P = 23.6\ \frac{lb}{in^2}$

$\rightarrow F = (23.6\ lb/in^2)(706.9\ in^2) = 16{,}683\,lb$

4.10 A simple shower for remote locations is designed with a cylindrical tank 500 mm in diameter and 1.800 m high as shown in **Fig. P4.10**. The water flows through a flapper valve in the bottom through a 75-mm-diameter opening. The flapper must be pushed upward to open the valve. How much force is required to open the valve?

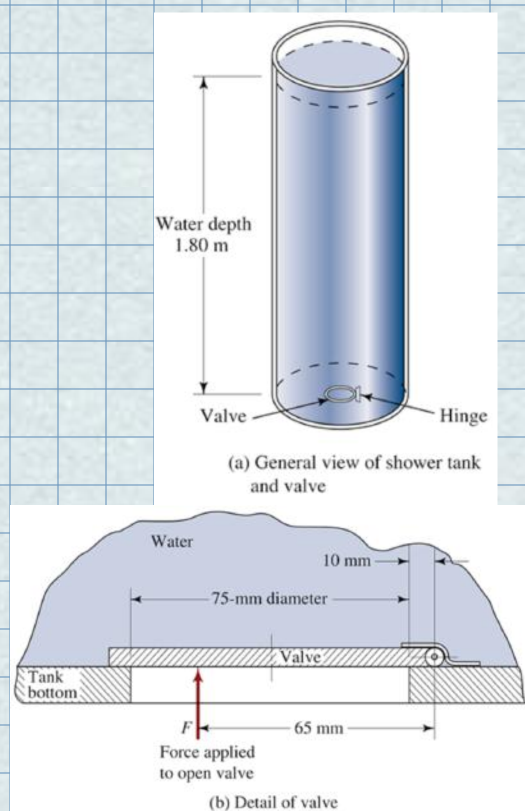
$P_B = P_{atm} + \gamma W\,(1.80\,m)$

$\gamma = (sg)_w\left(9.81\ \frac{kN}{m^3}\right) = (1)\left(9.81\ \frac{kN}{m^3}\right) = 9.81\ \frac{kN}{m^3}$

$\rightarrow P_B = 0 + \left(9.81\ \frac{kN}{m^3}\right)(1.80\,m) = 17.7\ kPa$

$A = \frac{\pi(500\,mm)^2}{4} = 0.20\,m^2$

$F = P_B A = \left(17.7\ \frac{kN}{m^2}\right)(0.20\,m^2) = 3.54\ kN$



(a) General view of shower tank and valve

(b) Detail of valve

4.17 If the wall in **Fig. P4.17** is 4 m long, calculate the total force on the wall due to the oil pressure. Also determine the location of the center of pressure and show the resultant force on the wall.

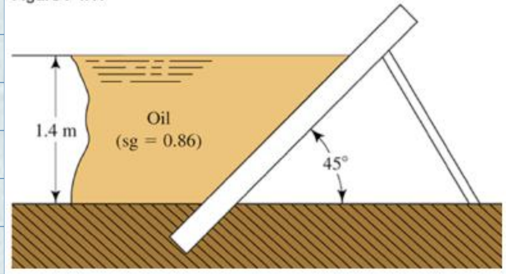


Figure P4.17

$\sin\theta = \frac{h}{L}$

$L = \frac{h}{\sin\theta} = \frac{1.4\text{m}}{\sin 45°} = 1.98\text{m}$

$A = (1.98\text{m})(4\text{m}) = 7.92\text{ m}^2$

$F = \gamma\left(\frac{h}{2}\right)A = \left(\frac{9.81\text{kN}}{\text{m}^3}\right)\left(\frac{1.4\text{m}}{2}\right)(7.92\text{m}^2) = 54.4\text{kN}$

$\frac{h}{3} = \frac{1.4\text{m}}{3} = 0.4\bar{7}\text{m}$

$\frac{L}{3} = \frac{1.98\text{m}}{3} = 0.66\text{m}$

$L_p = L - \frac{L}{3} = (1.98\text{m}) - (0.66\text{m}) = 1.32\text{ m}$

For each of the cases shown in **Figs. P4.18–4.29**, compute the magnitude of the resultant force on the indicated area and the location of the center of pressure. Show the resultant force on the area and clearly dimension its location.

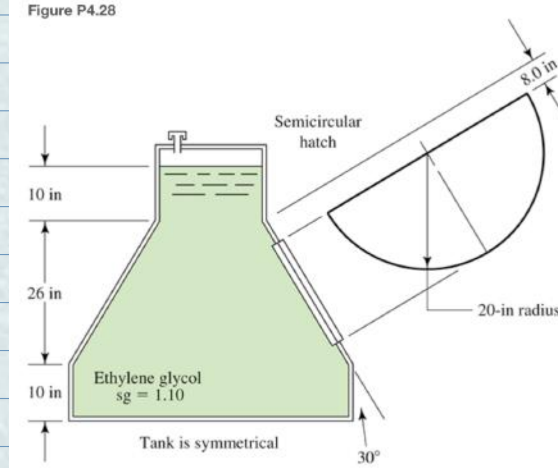


Figure P4.28

$(sg)_{eg} = 1.10$

$y = 8.49\text{in}$

$L_c = 8 + 8.49 + \frac{10}{\cos 30°} = 28.04\text{ in}$

$h_c = 28.04\cos 30° = 24.28\text{in}$

$F = \frac{(1.1)(68.47)}{12^3}(24.28)\left(\frac{\pi(20)^2}{2}\right) = 664.93\text{lbf}$

$L_p = \frac{I_c}{L_c A} = 28.04\text{ in} + \frac{52.35}{(28.04)\left(\frac{\pi(20)^2}{2}\right)} = 28.043\text{ in}$

4.42 **Figure P4.42** shows a tank of water with a circular pipe connected to its bottom. A circular gate seals the pipe opening to prohibit flow. To drain the tank, a winch is used to pull the gate open. Compute the amount of force that the winch cable must exert to open the gate.

$38\text{ in} = 0.97\text{m}$, $10\text{in} = 0.254\text{ m}$

$h_c = \frac{0.97}{2}\cos 30° = 0.42\text{ m}$ $\quad A = \frac{\pi(0.254)^2}{2} = 0.1\text{m}^2$

$F_{fluid} = 9.81(0.42)(0.1) = 0.41$

$L_p = \frac{2}{3}(0.97) = 0.64$

$F_{winch} = \frac{0.41(0.97 - 0.64)}{0.254} = 0.532 = 53.2\text{ kN}$

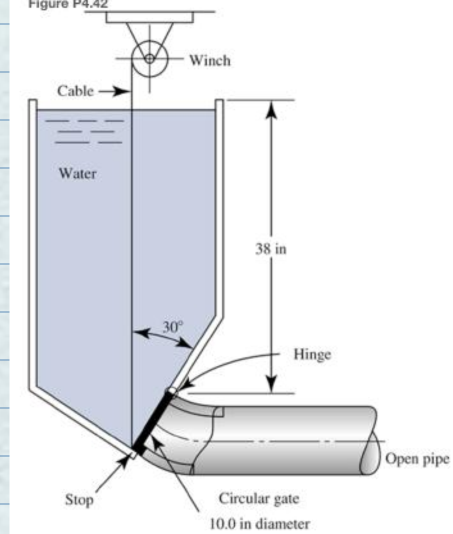
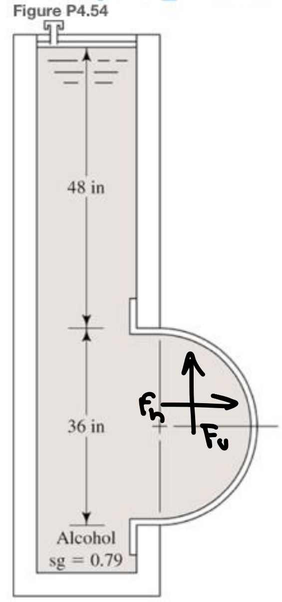


Figure P4.42

General Note for Problems 4.47–4.54. For each problem, one curved surface is shown restraining a body of static fluid. Compute the magnitude of the horizontal component of the force and compute the vertical component of the force exerted by the fluid on that surface. Then compute the magnitude of the resultant force and its direction. Show the resultant force acting on the curved surface. In each case, the surface of interest is a portion of a cylinder with the length of the surface given in the problem statement.

4.54 Use **Fig. P4.54**. The surface is 60 in long.

Figure P4.54



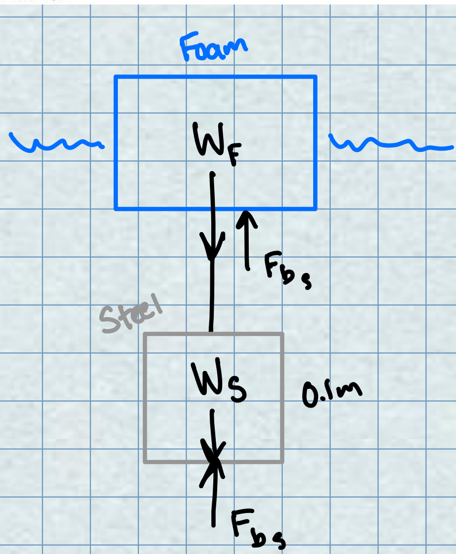
$$F_v = 9.81\left[(2.8+1.2)\,1.2 - \frac{\pi \times 1.2^2}{4}\right] 1.5$$

$\rightarrow F_v = 53.99\ \text{kN}$

$$x_v = \frac{[(2.8+L_2)1.2]\left(\frac{1.2}{2}\right) - \frac{\pi(1.2)^2}{4}(0.4)(1.2)}{[(2.8+1.2)1.2] - \frac{\pi(1.2)}{4}}$$

$\rightarrow x_v = 0.637\ \text{m}$

5.8 A steel cube 100 mm on a side weighs 80 N. We want to hold the cube in equilibrium under water by attaching a light foam buoy to it. If the foam weighs $470\ \text{N/m}^3$, what is the minimum required volume of the buoy?



$W_s = 80\ \text{N}$, $\rho_F = 470\ \text{N/m}^3$

$L = 0.1\ \text{m}$

$(F_b)_s = 9.81\ \text{N}$

$W_F = \gamma V_F = (470\ \text{N/m}^3)\, V_F$

$(F_b)_F = \rho_w g V_F = 9810\, V_F$

$\Sigma F_y = 0$

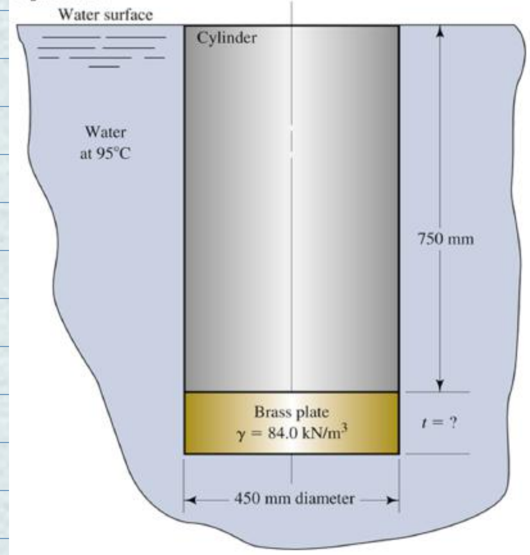
$F_{b_F} + F_{b_s} - W_F - W_s = 0$

$\rightarrow 9810\, V_F + 9.81 - 470\, V_F - 80 = 0$

$V_F = 7.515 \times 10^{-3}\ \text{m}^3$

5.24 A brass weight is to be attached to the bottom of the cylinder described in Problems 5.22 and 5.23, so that the cylinder will be completely submerged and neutrally buoyant in water at $95\,^{\circ}\mathrm{C}$. The brass is to be a cylinder with the same diameter as the original cylinder as shown in **Fig. P5.24**. What is the required thickness of the brass?

Figure P5.24



$T_w = 95°C$

$D = 450 \text{ mm} = 0.45 \text{m}$

$L = 750 \text{ mm} = 0.75 \text{m}$

$F_b + F_c - W_c - W_B = 0$

$W_c = \gamma V = \gamma\left(\frac{\pi}{4} D^2 L\right) = 6.45\left(\frac{3.14\,(0.45)^2\, 0.25}{4}\right)$

$\rightarrow W_c = 0.77 \text{ kN}$

$W_b = \gamma_b V_b = 84\left(\frac{\pi}{4}\right) D^2 t = 13.36t \text{ kN}$

$F_c = \gamma_f V_d = 9.44\left(\frac{\pi}{4}\right) D^2 L = 1.125 \text{ kN}$

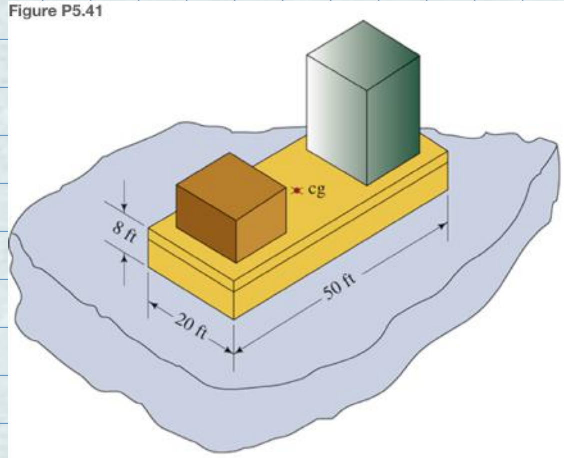
$F_b = \gamma_f V_d = 9.44\left(\frac{3.14\,(0.45)^2 t}{4}\right) = 1.5t \text{ kN}$

$1.5t + 1.125 - 0.77 - 13.36t = 0$

$\rightarrow t = 30 \text{ mm}$

5.41 The large platform shown in **Fig. P5.41** carries equipment and supplies to offshore installations. The total weight of the system is 450 000 lb, and its center of gravity is even with the top of the platform, 8 ft from the bottom. Will the platform be stable in seawater in the position shown?

Figure P5.41



$M_c > c_g$

$W = 450{,}000 \text{ lb}$

$F_b = W$

$V_d = Lbh = 1000x$

$F_b = 64{,}000x \text{ lb}$

$\rightarrow 64{,}000x = 450{,}000 \text{ lb}$

$\rightarrow x = 7.031 \text{ ft}$

$c_b = \frac{7.03}{2} = 3.515 \text{ ft}$

$I = \frac{16^3}{12} = 33{,}300 \text{ ft}^2$

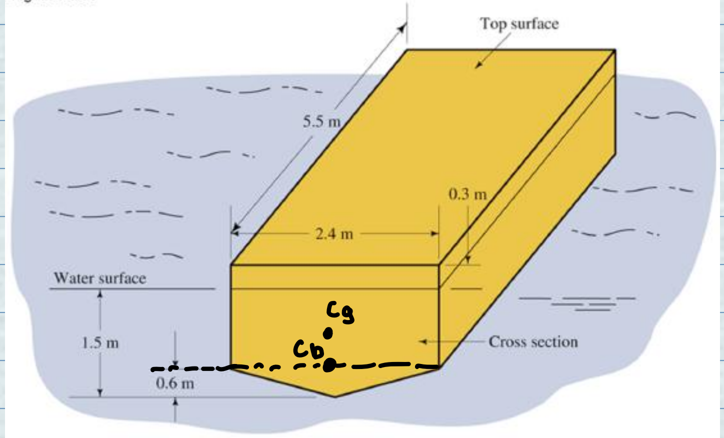
$M_B = \frac{I}{V_d} = \frac{33{,}300}{7030} = 4.74 \text{ ft}$

$M_c = C_b + M13 = 3.515 + 4.74 = 8.25$

$8.25 > c_g \quad \therefore$ Platform is stable

5.61 A boat is shown in **Fig. P5.61**. Its geometry at the water line is the same as the top surface. The hull is solid. Is the boat stable?

Figure P5.61



$L_c + MB > L_{cg}$ $\qquad MB = \frac{I}{V_d}$ where $I = \frac{LW^3}{12}$

$\bar{y} = 0.8625\text{m}$

$L_{cg} = 0.8625\text{m}$, $L_{cb} = \frac{1.5-3}{2} = 0.6\text{m}$

$I = \frac{5.5(2.4)^3}{12} + (13.2)(0.1625)^2 = 6.6845\text{m}^3$

$MB = \frac{I}{V} = \frac{6.6845}{15.84} = 0.422$

the boat is stable

Weekly Reflection

Looking back on the modules for Forces Due to Static Fluids, I realized the fundamental role that forces due to static fluids play in understanding fluid behavior. I learned that these forces are intrinsically connected to the pressure exerted by the fluid. I also improved my skills in constructing and interpreting free body diagrams, as well as identifying and calculating resultant forces. One of the problems I reviewed introduced the concept of assuming a fictional fluid above a surface of interest when the fluid in question is below this surface, which was a practical approach I learned.

In regards to buoyancy and stability, I came to understand that the center of buoyancy is essentially the centroid of the displaced volume of a body in a fluid. The conditions for stability became clearer: for submerged bodies to be stable, their center of gravity must lie below the center of buoyancy. On the other hand, for floating bodies, stability is ensured when the center gravity is below the metacenter, with the metacenter being a function of the second moment of area and the displaced volume, $\underline{MB = I/V_d}$.