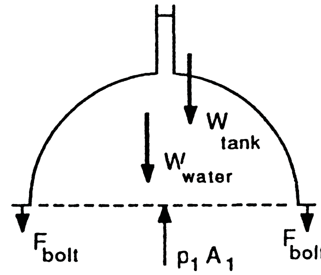
Then summation of vertical forces on this 25-cm-wide freebody gives



$$\sum F_z = 0 = p_1A_1 - W_{water} - W_{tank} - 2F_{bolt}$$

$$= (39160)(4 \times 0.25) - (9790)(\pi/2)(2)^2(0.25) - (4500)/4 - 2F_{bolt},$$

Solve for $F_{one\ bolt} = \mathbf{11300\ N}$ *Ans.*

2.93 In Fig. P2.93 a one-quadrant spherical shell of radius R is submerged in liquid of specific weight γ and depth h > R. Derive an analytic expression for the hydrodynamic force F on the shell and its line of action.

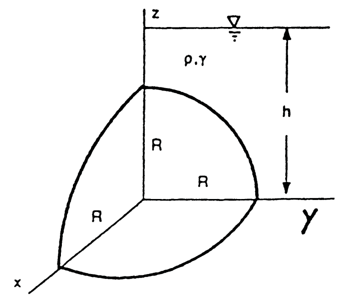


Fig. P2.93

Solution: The two horizontal components are identical in magnitude and equal to the force on the quarter-circle side panels, whose centroids are $(4R/3\pi)$ above the bottom:

$$\text{Horizontal components:}\quad F_x = F_y = \gamma h_{CG}A_{vert} = \gamma\left(h - \frac{4R}{3\pi}\right)\frac{\pi}{4}R^2$$

Similarly, the vertical component is the weight of the fluid above the spherical surface:

$$F_z = W_{cylinder} - W_{sphere} = \gamma\left(\frac{\pi}{4}R^2h\right) - \gamma\left(\frac{1}{8}\frac{4}{3}\pi R^3\right) = \gamma\frac{\pi}{4}R^2\left(h - \frac{2R}{3}\right)$$

There is no need to find the (complicated) centers of pressure for these three components, for we know that the resultant on a spherical surface <u>*must pass through the center*</u>. Thus

$$F = \left[F_x^2 + F_y^2 + F_z^2\right]^{1/2} = \boldsymbol{\gamma\frac{\pi}{4}R^2\left[(h - 2R/3)^2 + 2(h - 4R/3\pi)^2\right]^{1/2}} \quad \textit{Ans.}$$

2.94 The 4-ft-diameter log (SG = 0.80) in Fig. P2.94 is 8 ft long into the paper and dams water as shown. Compute the net vertical and horizontal reactions at point C.

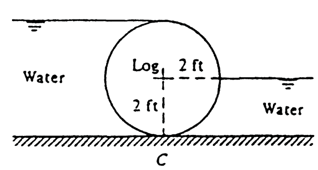
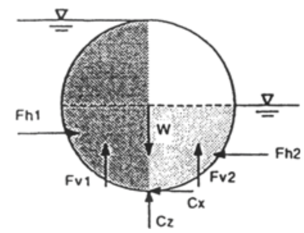


Fig. P2.94

Solution: With respect to the sketch at right, the horizontal components of hydrostatic force are given by

$$F_{h1} = (62.4)(2)(4\times 8) = 3994 \text{ lbf}$$

$$F_{h2} = (62.4)(1)(2\times 8) = 998 \text{ lbf}$$



The vertical components of hydrostatic force equal the weight of water in the shaded areas:

$$F_{v1} = (62.4)\frac{\pi}{2}(2)^2(8) = 3137 \text{ lbf}$$

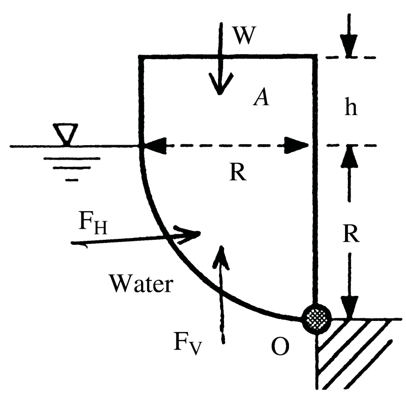
$$F_{v2} = (62.4)\frac{\pi}{4}(2)^2(8) = 1568 \text{ lbf}$$

The weight of the log is $W_{log} = (0.8\times 62.4)\pi(2)^2(8) = 5018$ lbf. Then the reactions at C are found by summation of forces on the log freebody:

$$\sum F_x = 0 = 3994 - 998 - C_x, \quad \text{or} \quad C_x = \mathbf{2996\ lbf} \quad \textit{Ans.}$$

$$\sum F_z = 0 = C_z - 5018 + 3137 + 1568, \quad \text{or} \quad C_z = \mathbf{313\ lbf} \quad \textit{Ans.}$$

2.95 The uniform body A in the figure has width *b* into the paper and is in static equilibrium when pivoted about hinge O. What is the specific gravity of this body when (a) h = 0; and (b) h = R?



Solution: The water causes a horizontal and a vertical force on the body, as shown:

$$F_H = \gamma\frac{R}{2}Rb \quad at \quad \frac{R}{3} \text{ above } O,$$

$$F_V = \gamma\frac{\pi}{4}R^2 b \quad at \quad \frac{4R}{3\pi} \text{ to the left of } O$$

These must balance the moment of the body weight W about O:

$$\sum M_O = \frac{\gamma R^2 b}{2}\left(\frac{R}{3}\right) + \frac{\gamma\pi R^2 b}{4}\left(\frac{4R}{3\pi}\right) - \frac{\gamma_s \pi R^2 b}{4}\left(\frac{4R}{3\pi}\right) - \gamma_s Rhb\left(\frac{R}{2}\right) = 0$$