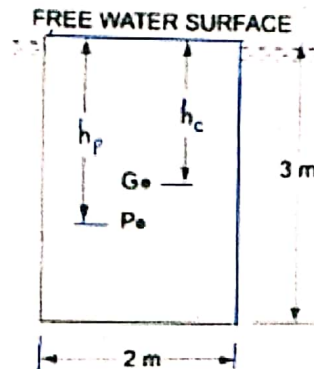


Problem 3.1 /

A rectangular plane surface is 2 m wide and 3 m deep. It lies in vertical plane in water. Determine the total pressure and position of center of pressure on the plane surface when its upper edge is horizontal and (a) coincides with water surface, (b) 2.5 m below the free water surface.

Solution:



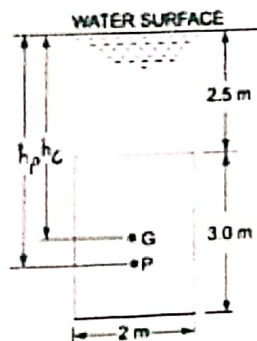
$$(a) \quad \text{Area } (A) = 2 \times 3 = 6 \text{ m}^2, \quad h_c = \frac{1}{2} \times 3 = 1.5 \text{ m}$$

$$F = \rho g A h_c, \quad F = 1000 \times 9.81 \times 6 \times 1.5 = 88290 \text{ N}$$

$$h_p = \frac{I_G}{A h_c} + h_c, \quad I_G = \frac{b d^3}{12} = \frac{2 \times 3^3}{12} = 4.5 \text{ m}^4$$

$$h_p = \frac{4.5}{6 \times 1.5} + 1.5 = 0.5 + 1.5 = 2 \text{ m}$$

(b)



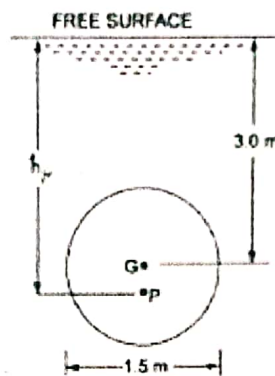
$$h_c = 2.5 + \frac{3}{2} = 4 \text{ m}, \quad F = \rho g A h_c = 1000 \times 9.81 \times 6 \times 4 = 235440 \text{ N}$$

$$h_p = \frac{I_G}{A h_c} + h_c, \quad h_p = \frac{4.5}{6 \times 4} + 4 = 0.1875 + 4 = 4.1875 \text{ m}$$

Problem 3.2 /

Determine the total pressure force on a circular plate of diameter 1.5 m which is placed vertically in water in such a way that the center of the plate is 3 m below the free surface of water. Find the position of center of pressure also.

Solution:



$$A = \frac{\pi}{4} \times (1.5)^2 = 1.767 \text{ m}^2, \quad h_c = 3 \text{ m}$$

$$F = \rho g A h_c = 1000 \times 9.81 \times 1.767 \times 3 = 52002.81 \text{ N}$$

$$h_p = \frac{I_G}{A h_c} + h_c, \quad I_G = \frac{\pi d^4}{64} = \frac{\pi (1.5)^4}{64} = 0.2485 \text{ m}^4$$

$$h_p = \frac{0.2485}{1.767 \times 3} + 3 = 0.0468 + 3 = 3.0468 \text{ m}$$

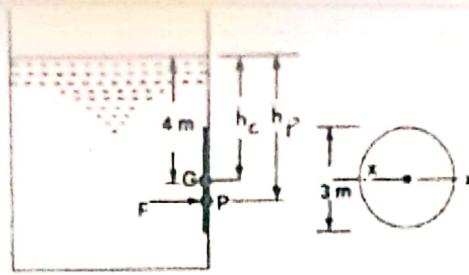
Problem 3.3 /

A circular opening, 3 m diameter, in a vertical side of a tank is closed by a disc of 3 m diameter which can rotate about a horizontal diameter, calculate (1) the force on the disc, (2) when the head of water above the horizontal diameter is 4 m, what is the value of center pressure (h_p)?

Solution:

$$(1) \text{ Area } (A) = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (3)^2 = 7.068 \text{ m}^2, \quad h_c = 4 \text{ m}$$

$$F = \rho g A h_c = 1000 \times 9.81 \times 7.068 \times 4 = 277368 \text{ N}$$



(2)

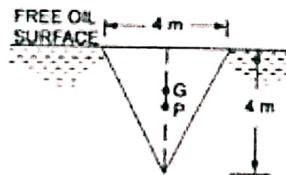
$$h_p = \frac{I_G}{A h_c} + h_c, \quad I_G = \frac{\pi}{64} d^4 = \frac{\pi}{64} \times 3^4 = 3.974 \text{ m}^4$$

$$h_p = \frac{3.974}{7.068 \times 4} + 4 = 0.14 + 4 = 4.14 \text{ m}$$

Problem 3.4 /

Determine the total pressure force and center of pressure on an isosceles triangular plate of base 4 m and altitude 4 m, when it is immersed vertically in an oil of sp. gr. 0.9. The base of the plate coincides with the free surface of oil.

Solution :



$$\text{Area (A)} = \frac{b \times h}{2} = \frac{4 \times 4}{2} = 8 \text{ m}^2, \quad h_c = \frac{1}{3} h = \frac{1}{3} \times 4 = 1.33 \text{ m}$$

$$F = \rho g A h_c = 0.9 \times 1000 \times 9.81 \times 1.33 = 9597.6 \text{ N}$$

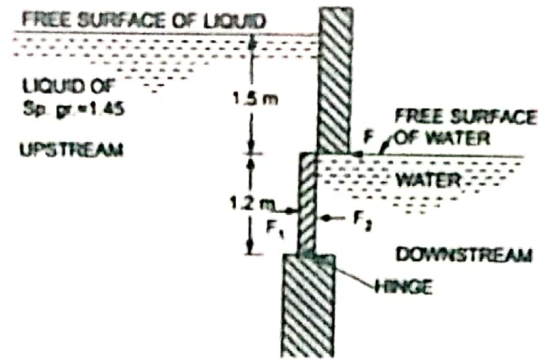
$$h_p = \frac{I_G}{A h_c} + h_c, \quad I_G = \frac{b h^3}{36} = \frac{4 \times 4^3}{36} = 7.11 \text{ m}^4$$

$$h_p = \frac{7.11}{8 \times 1.33} + 1.33 = 0.666 + 1.33 = 1.99 \text{ m}$$

Problem 3.5 /

A vertical sluice gate is used to cover an opening in a dam. The opening is 2 m wide and 1.2 m high. On the upstream of the gate, the liquid of sp.gr. 1.45, lies up to a height of 1.5 m above the top of the gate, whereas on the downstream side the water is available up to height touching the top of the gate. Find the resultant force acting on the gate and position of center of pressure.

Solution:



(1)

$$\text{Area (A)} = b \times d = 2 \times 1.2 = 2.4 \text{ m}^2$$

$$\text{For liquid : } h_{cL} = 1.5 + \frac{1.2}{2} = 2.1 \text{ m}$$

$$F_1 = \rho_L g A h_{cL} = 1,45 \times 1000 \times 9.81 \times 2.4 \times 2.1 = 71691 \text{ N}$$

$$h_{pL} = \frac{I_G}{A h_{cL}} + h_{cL} \quad , \quad I_G = \frac{b d^3}{12} = \frac{2 \times 1.2^3}{12} = 0.288 \text{ m}^4$$

$$h_{pL} = \frac{0.288}{2.4 \times 2.1} + 2.1 = 0.0571 + 2.1 = 2.1571 \text{ m}$$

$$\text{For water : } h_{cw} = \frac{1}{2} \times 1.2 = 0.6 \text{ m}$$

$$F_2 = \rho_w g A h_{cw} = 1000 \times 9.81 \times 2.4 \times 0.6 = 14126 \text{ N}$$

$$h_{pw} = \frac{I_G}{A h_{cw}} + h_{cw} \quad , \quad h_{pw} = \frac{0.288}{2.4 \times 0.6} + 0.6 = 0.2 + 0.6 = 0.8 \text{ m}$$

$$\text{Resultant force on the gate (R)} = F_1 - F_2 = 57565 \text{ N}$$

(2) position of center pressure of resultant force (R):

Take the moments of forces at the hinge:

$$57565 \times h_p = 71691 \times [(1.5 + 1.2) - 2.1571] - 14126 \times (1.2 - 0.8)$$

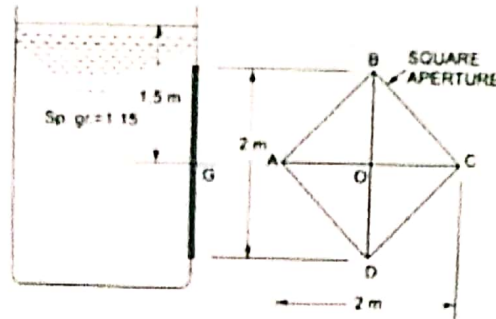
$$h_p = 0.578 \text{ m}$$

Problem 3.6 /

A square aperture in the vertical side of a tank has one diagonal vertical and is completely covered by a plane hinged along one of the upper sides of

aperture. The diagonals of the aperture are 2 m long and the tank contains a liquid of specific gravity 1.15. The center of aperture is 1.5 m below the free surface. Calculate the thrust (force) exerted on the plate by the liquid and position of its center of pressure.

Solution:



Area of square aperture (A) = Area of ΔACB + Area of ΔACD

$$= \frac{2 \times 1}{2} + \frac{2 \times 1}{2} = 2 \text{ m}^2$$

$$h_c = 1.5 \text{ m}$$

$$F = \rho g A h_c = 1.15 \times 1000 \times 9.81 \times 2 \times 1.5 = 33844.5 \text{ N}$$

$$h_p = \frac{I_G}{A h_c} + h_c, \quad I_G = \frac{b_1 h_1^3}{12} + \frac{b_2 h_2^3}{12} = \frac{2 \times 1^3}{12} + \frac{2 \times 1^3}{12}$$

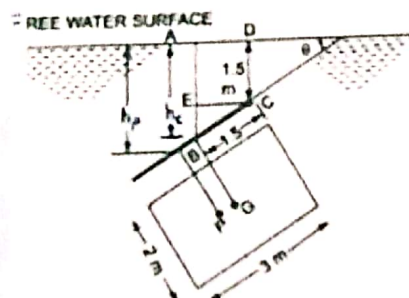
$$= \frac{1}{6} + \frac{1}{6} = \frac{1}{3} \text{ m}^4$$

$$h_p = \frac{\frac{1}{3}}{2 \times 1.5} + 1.5 = 1.611 \text{ m}$$

Problem 3.7 /

A rectangular plane surface 2 m wide and 3 m deep lies in water in such a way that its plane makes an angle of 30° with the free surface of water. Determine the total pressure force and position of center of pressure when the upper edge is 1.5 m below the free water surface.

Solution:



$$\text{Area (A)} = 3 \times 2 = 6 \text{ m}^2$$

$$h_c = 1.5 + BC \sin \theta = 1.5 + 1.5 \sin 30^\circ = 1.5 + 0.75 = 2.25 \text{ m}$$

$$F = \rho_w g A h_c = 1000 \times 9.81 \times 6 \times 2.25 = 132435 \text{ N}$$

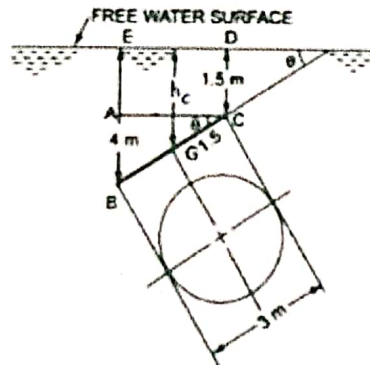
$$h_p = \frac{I_G \sin^2 \theta}{A h_c} + h_c, \quad I_G = \frac{b d^3}{12} = \frac{2 \times 3^3}{12} = 4.5 \text{ m}^4$$

$$h_p = \frac{4.5 \times 0.25}{6 \times 2.25} + 2.25 = 0.0833 + 2.25 = 2.3333 \text{ m}$$

Problem 3.8 /

A circular plate 3 m diameter is immersed in water in such a way that its greatest and least depth below the free surface are 4 m and 3 m respectively. Determine the total pressure force on one face of the plate and position of the center of pressure.

Solution:



$$\text{Area (A)} = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 3^2 = 7.068 \text{ m}^2$$

$$\sin \theta = \frac{AB}{BC} = \frac{4 - 1.5}{3} = 0.8333$$

$$h_c = 1.5 + GC \sin \theta = 1.5 + 1.5 \times 0.8333 = 2.749 \text{ m}$$

$$F = \rho_w g A h_c = 1000 \times 9.81 \times 7.068 \times 2.749 = 190621 \text{ N}$$

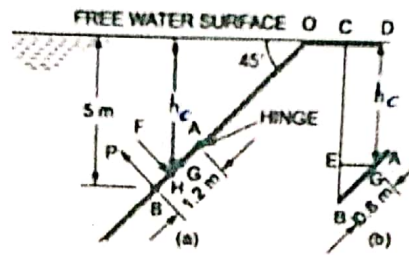
$$h_p = \frac{I_G \sin^2 \theta}{A h_c} + h_c, \quad I_G = \frac{\pi}{64} d^4 = \frac{\pi}{64} \times 3^4 = 3.976 \text{ m}^4$$

$$h_p = \frac{3.976 \times (0.8333)^2}{7.068 \times 2.749} + 2.749 = 0.142 + 2.749 = 2.891 \text{ m}$$

Problem 3.9 /

An inclined rectangular sluice gate AB, 1.2 m by 5 m size as shown in Fig. is installed to control the discharge of water. The end A is hinged. Determine the force normal to the gate applied at B to open it .

Solution:



$$\text{Area of gate (A)} = 1.2 \times 5 = 6 \text{ m}^2$$

$$h_c = 5 - BG \sin 45^\circ = 5 - 0.6 \times \frac{1}{\sqrt{2}} = 4.576 \text{ m}$$

$$F = \rho_w g A h_c = 1000 \times 9.81 \times 6 \times 4.576 = 269\,343 \text{ N}$$

$$h_p = \frac{I_G \sin^2 \theta}{A h_c} + h_c, \quad I_G = \frac{b d^3}{12} = \frac{5 \times 1.2^3}{12} = 0.72 \text{ m}^4$$

$$h_p = \frac{0.72 (\sin^2 45)}{6 \times 4.576} + 4.576 = 0.013 + 4.576 = 4.589 \text{ m}$$

$$\sin 45^\circ = \frac{h_p}{OH}, \quad OH = \frac{h_p}{\sin 45} = \frac{4.589}{\frac{1}{\sqrt{2}}} = 6.489 \text{ m}$$

$$\sin 45^\circ = \frac{5}{BO}, \quad BO = 5 \times \sqrt{2} = 7.071 \text{ m}$$

$$BH = BO - OH = 7.071 - 6.489 = 0.582 \text{ m}$$

$$AH = AB - BH = 1.2 - 0.582 = 0.618 \text{ m}$$

Taking the moments about the hinge A:

$$P \times AB = F \times AH$$

Where P is the force normal to the gate applied at B,

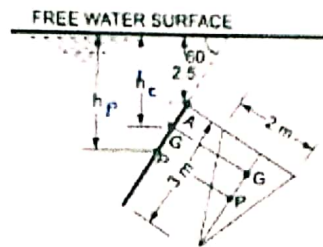
$$P \times 1.2 = 269343 \times 0.618$$

$$P = 138708 \text{ N}$$

Problem 3.10 /

Find the total pressure force and position of center of pressure on a triangular plate of base 2 m and height 3 m which is immersed in water in such a way that the plane of the plate makes an angle of 60° with the free surface of the water. The base of the plate is parallel to water surface and at a depth of 2.5 m from water surface.

Solution:



$$\text{Area (A)} = \frac{b \times h}{2} = \frac{2 \times 3}{2} = 3 \text{ m}^2$$

$$h_c = 2.5 + AG \sin 60^\circ = 2.5 + \frac{1}{3} \times 3 \times \frac{\sqrt{3}}{2} = 3.366 \text{ m}$$

$$F = \rho_w g A h_c = 1000 \times 9.81 \times 3 \times 3.366 = 99061 \text{ N}$$

$$h_p = \frac{I_G \sin^2 \theta}{A h_c} + h_c, \quad I_G = \frac{b h^3}{36} = \frac{2 \times 3^3}{36} = 1.5 \text{ m}^4$$

$$h_p = \frac{1.5 \sin^2 60^\circ}{3 \times 3.366} + 3.366 = 0.111 + 3.366 = 3.477 \text{ m}$$