Module 3: Hydrostatic forces on submerged bodies

Lecture 8: Examples

- Examples on forces on stationary submerged bodies

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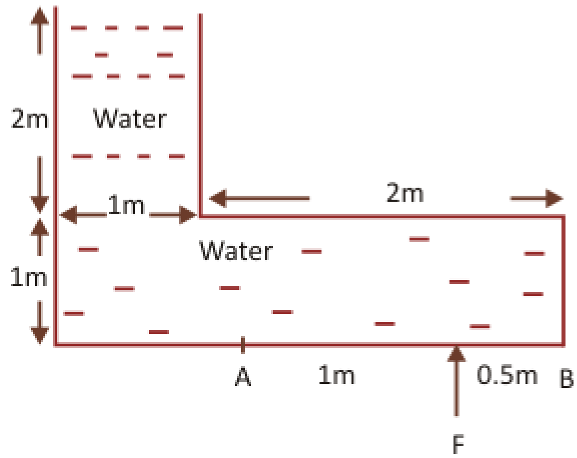
Examples on forces on stationary submerged bodies

Example1:

See the drawing below. A tank is filled with water. At the bottom of the tank, a gate AB is hinged at A. To keep the gate in place, a vertical force, $\vec{F}$ is applied at the distance of 1m from the hinge. Compute $\vec{F}$. Given g =10 m/s^2. The width of the gate is 2 m.



(Fig. 8a)

Weight of water over AB will make the gate open in the clockwise direction. F acting vertically upward will keep the gate in place (rotational equilibrium). Note that the weight of the water-column of height 3 m will be acting on the gate and be uniform.

Therefore, $W = (h\rho g) \times \text{Area of the gate}$

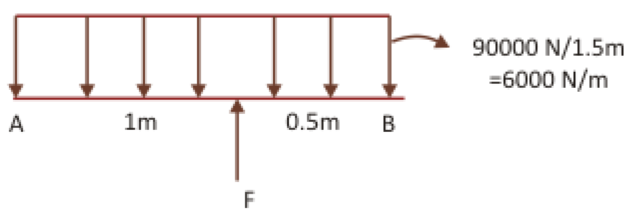
$= 3 \times 1000 \times 10 \times (2 \times 1.5)$

$= 90000 \text{ N}$

And, this force will act at a distance of 0.75 m from A.

$\therefore\ 9000 \times 0.75 = \text{F x 1}$ (Moment about A)

$\text{F} = 6700 \text{ N}$



(Fig. 8b)

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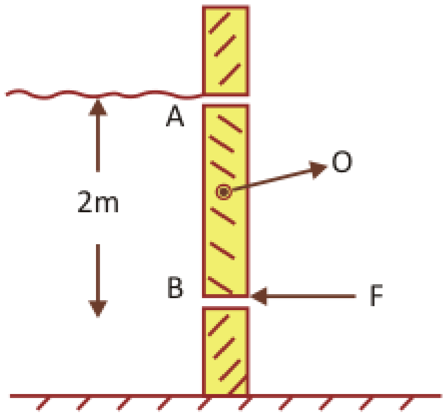
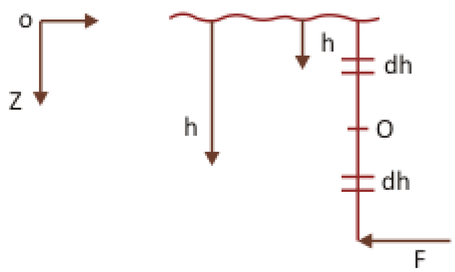
Example 2:

Consider a vertical water-gate AB of height 2 m hinged at 'O', the center of the gate. Determine the horizontal force $\vec{F}$ required to hold the gate in place. The gate is 1 m wide.



(Fig. 8c)

Consider the section AO (above the hinge). The hydrostatic pressure-force acting horizontally will make the gate rotate in the clockwise direction, whereas that below the hinge 'O' will make the gate rotate in the anti-clockwise direction. Take moment about 'O' of these forces and equate to that of F:



(Fig. 8d)

$$\int_0^1 \underbrace{\rho g h}_{\text{pressure}} \underbrace{(1-h)}_{\text{distance}} \underbrace{dh.1}_{\text{area}} - \int_1^2 \rho g h\,(h-1)dh.1 + F \times 1 = 0$$

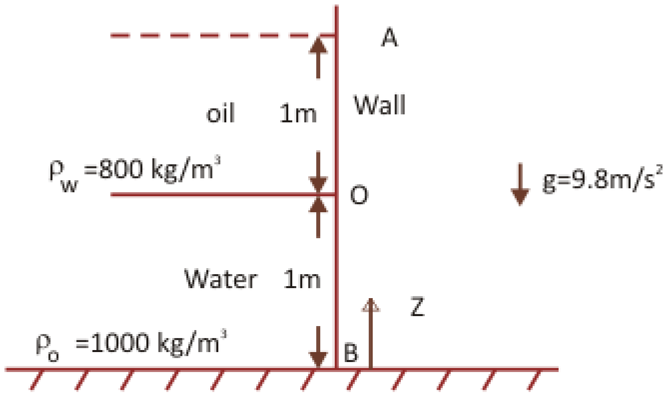
$$\rho g \left(\frac{h^2}{2} - \frac{h^3}{3}\right)\Big|_0^1 - \rho g \left(\frac{h^3}{3} - \frac{h^2}{2}\right)\Big|_1^2 + F = 0$$

$$1000 \times 9.8\left({}^1\!/_2 - {}^1\!/_3 - {}^8\!/_3 + 2 + {}^1\!/_3 - {}^1\!/_2\right) + F = 0$$

$$F = 6533 \text{ N}$$

Example 3:

See the figure below. On one-side of the wall, AB, are filled two immiscible liquids, oil and water. Calculate the horizontal force acting on the wall. Plot pressure-distribution. Assume the width of the wall = 0.5 m



(Fig. 8e)

Horizontal force acting on AO

$= (\text{pressure at the centroid of AO}) \times \text{area of AO}$

$= (0.5 \times 800 \times 9.8) \times (1\text{m} \times 0.5\text{m})$

$= 1960 \text{ N}$

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Horizontal force acting on OB

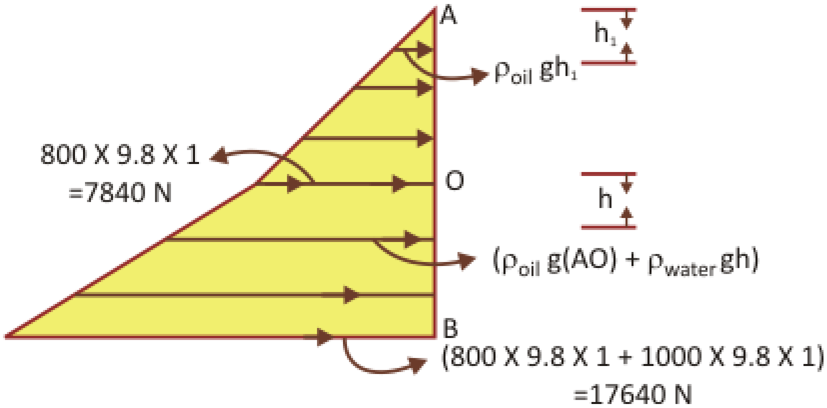
$$= (\text{pressure at the centroid of OB}) \times \text{area of OB}$$

$$= ((h\rho g)_{\text{oil at O}} + (h\rho g)_{\text{centroid of OB}}) \times (1\text{m} \times 0.5\text{m})$$

$$= (1 \times 800 \times 9.8 + 0.5 \times 1000 \times 9.8) \quad \times 0.5$$

$$= 6370 \text{ N}$$

Pressure-distribution is linear



(Fig. 8f)