٣ بلى

F/b → 3

٢٠٥

الفرقة الأولى

قسم مدني

فلويد

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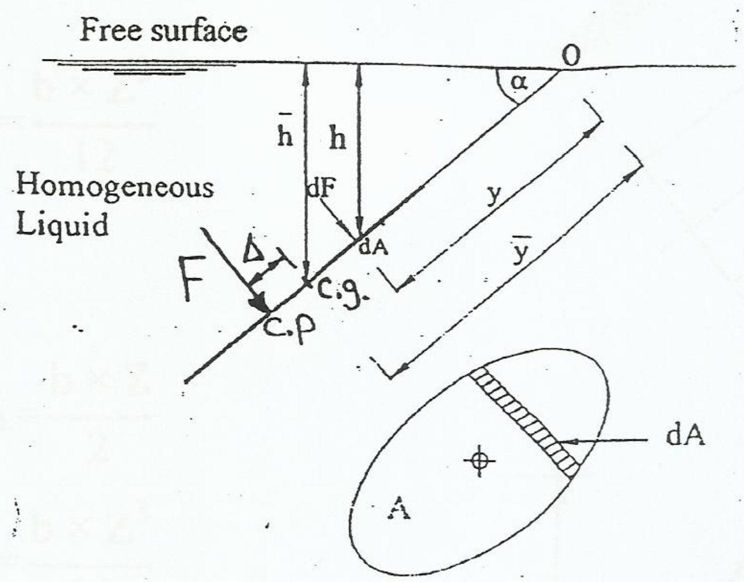
3 HYDROSTATIC FORCES ON SUBMERGED PLANE SURFACES



c.g. = center of gravity
c.p. = center of pressure
A = area of immersed surface (to the page)
I = moment of inertia (about the axis to the page)
h = **vertical distance** from the free surface to the c.g.
y = **inclined distance** form the free surface to the c.g.
Δ = inclined distance between (c.g) and (c.p)
α = inclination angle (with the free surface)

Rules:

- Hydrostatic Force

$$\boxed{F = \gamma A \bar{h}}$$

- Point of application

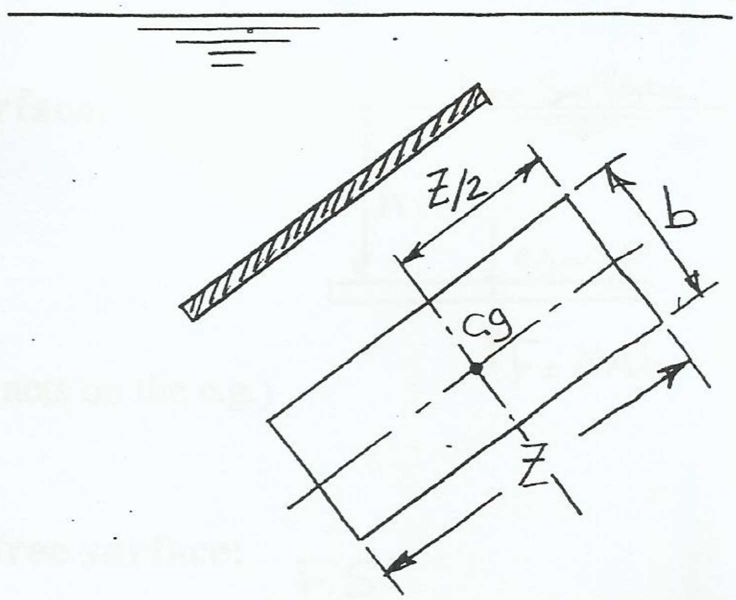
$$\boxed{\Delta = \frac{I}{A.\bar{y}}} \quad \text{where: } \bar{y} = \frac{\bar{h}}{\sin\alpha}$$

➢ Properties of Areas:

- **Rectangle:**

$$A = b \times Z$$

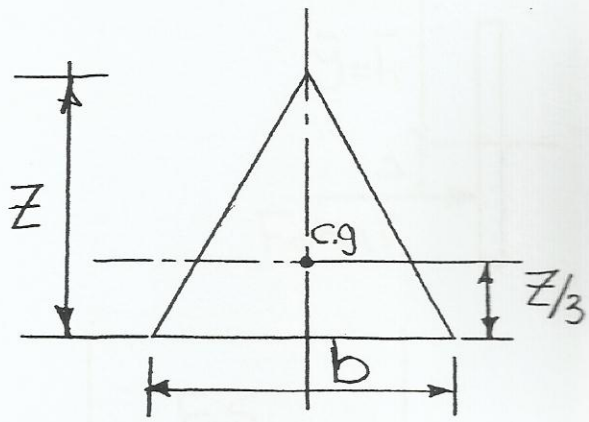
$$I = \frac{b \times Z^3}{12}$$



- **Triangle:**

$$A = \frac{b \times Z}{2}$$

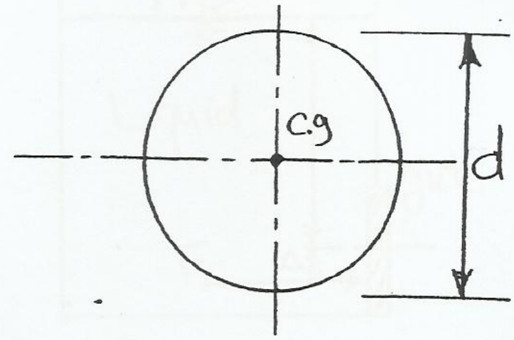
$$I = \frac{b \times Z^3}{36}$$



- **Circle:**

$$A = \frac{\pi \times d^2}{4}$$

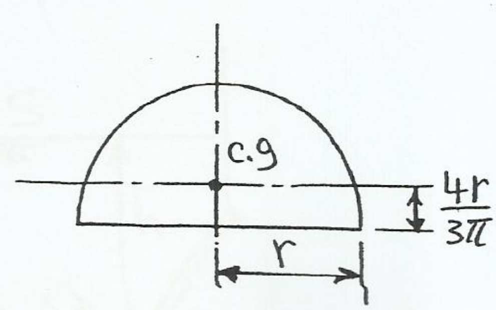
$$I = \frac{\pi \times d^4}{64}$$



- **Semicircle:**

$$A = \frac{\pi \times d^2}{8}$$

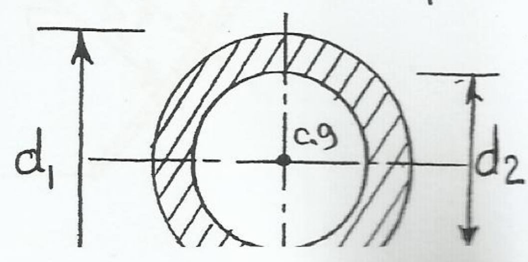
$$I = \frac{\pi \times d^4}{128} - \frac{d^4}{18\,\pi} \simeq \mathbf{0.11\,r^2}$$



- **Hollow Circle**

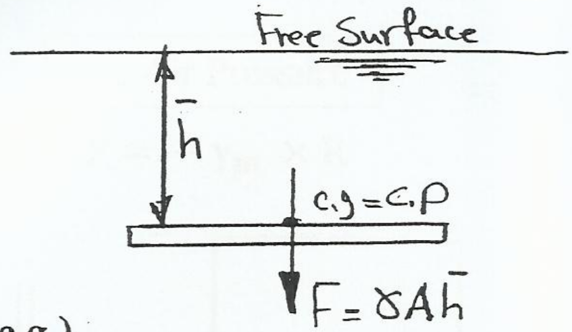
$$A = \frac{\pi}{4}\left({d_1}^2 - {d_2}^2\right)$$

$$I = \frac{\pi}{64}\left({d_1}^4 - {d_2}^4\right)$$



➢ Special Cases:

- **Surfaces parallel to the free surface:**

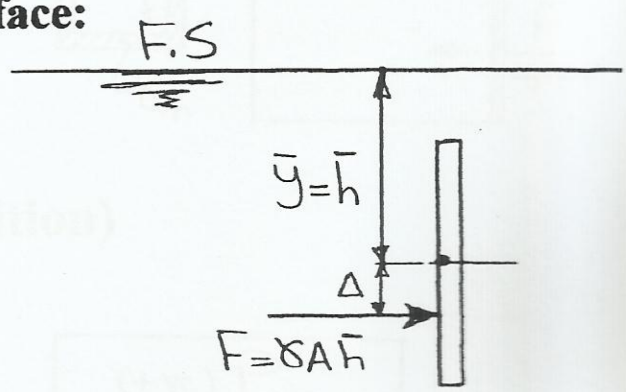


$\alpha = \text{Zero} \quad \rightarrow \quad \bar{y} = \dfrac{\bar{h}}{\sin\alpha} = \infty$

$\therefore \Delta = \text{Zero}$

$\rightarrow$ $\boxed{\text{c. g.} = \text{c. p.}}$ (The force acts on the c.g.)

- **Surfaces perpendicular to the free surface:**

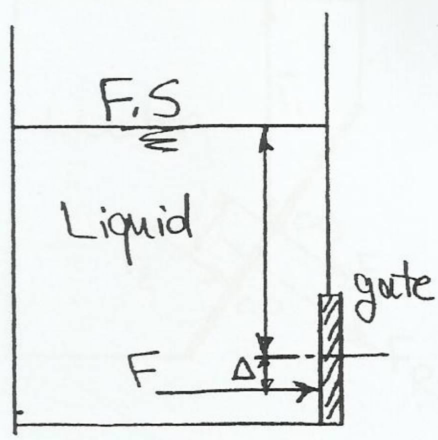


$\alpha = 90° \quad \rightarrow \quad \sin\alpha = 1$

$\boxed{\therefore \bar{h} = \bar{y}}$

➢ Cases of Problems:

1)One Liquid:

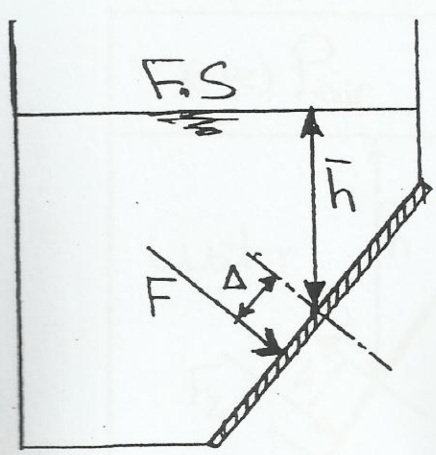


Liquid surface is free (P = 0)

$\rightarrow \quad \bar{h} = \bar{y}$ (Vertical gate)

$\therefore F = \gamma \times A \times \bar{h} \qquad \Delta = \dfrac{I}{A \cdot \bar{y}}$

For Inclined gate



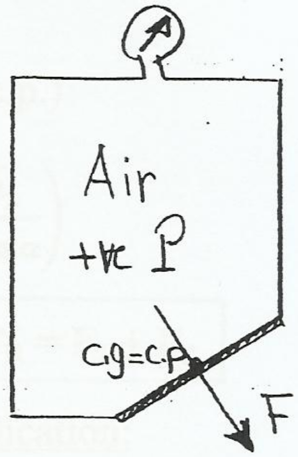
$\bar{y} = \dfrac{\bar{h}}{\sin\alpha}$

$\therefore F = \gamma \times A \times \bar{h} \qquad \Delta = \dfrac{I}{A \cdot \bar{y}}$

2) <u>Air:</u>

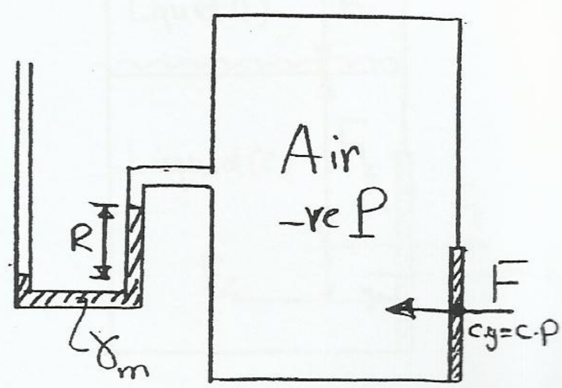
$$\boxed{\begin{aligned} c.p &= c.g \\ F &= P \times A \end{aligned}}$$

+ve Air Pressure



-ve Air Pressure

$$P = -\gamma_m \times R$$



3) <u>Liquid + Air:</u> (Solving by Superposition)

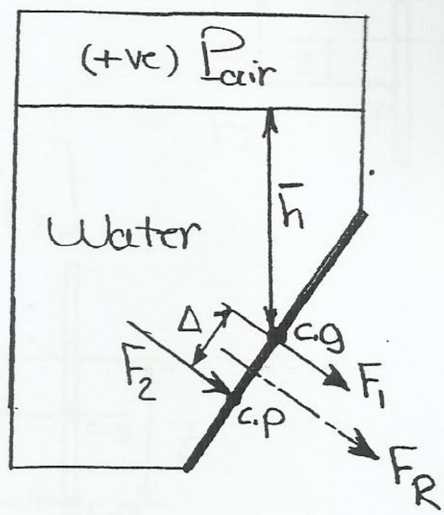
<u>Liquid & (+ve) Air pressure</u>

$\boxed{F_1 = P \times A}$ (at c.g.)

$\boxed{F_2 = \gamma_w \times A \times \bar{h}}$ (at c.p.)

$$\Delta = \frac{I}{A \cdot \bar{y}_2} \quad \left(\bar{y} = \frac{\bar{h}}{\sin\alpha}\right)$$

Resultant Force $\boxed{F_R = F_1 + F_2}$



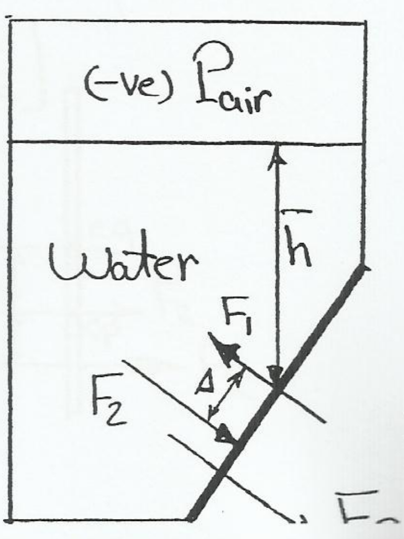
<u>Liquid & (-ve) Air pressure</u>

$\boxed{F_1 = P \times A}$ (at c.g.)

$\boxed{F_2 = \gamma_w \times A \times \bar{h}}$ (at c.p.)

$$\Delta = \frac{I}{A \cdot \bar{y}_2} \quad \left(\bar{y} = \frac{\bar{h}}{\sin\alpha}\right)$$

Resultant Force $\boxed{F_R = F_1 - F_2}$



If $F_2 > F_1$

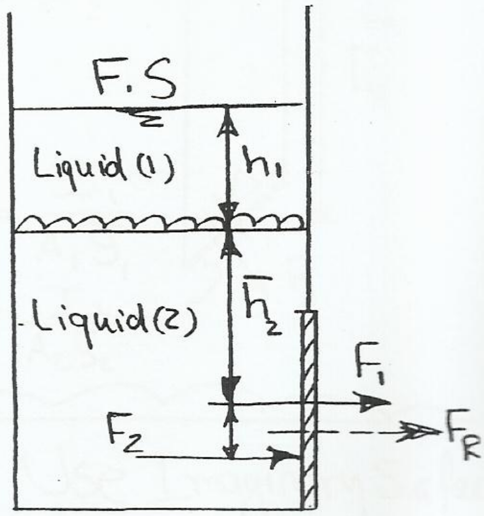
4) **Two Liquids:** (Solving by Superposition)

$P = \gamma_1 \times h_1$

$F_1 = P \times A$ (at c.g.)

$F_2 = \gamma_2 \times A \times \overline{h}_2$ (at c.p.)

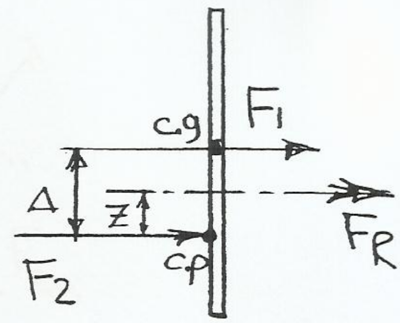
$$\Delta = \frac{I}{A \cdot \overline{y}_2} \qquad \left(\overline{y}_2 = \frac{\overline{h}_2}{\sin\alpha}\right)$$



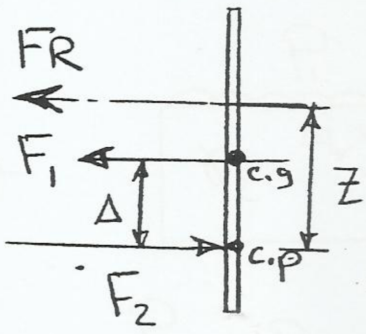
Resultant Force $\boxed{F_R = F_1 + F_2}$

To get (F_R) point of application:

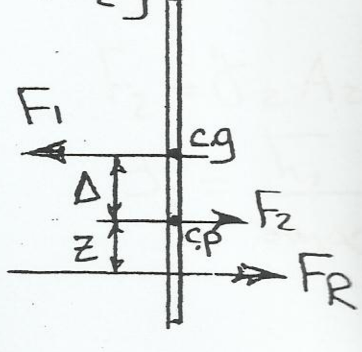
$\sum M$ @ c.p. = zero $\rightarrow$ $F_1 \times \Delta = F_R \times Z$ $\rightarrow$ get $Z < \Delta$



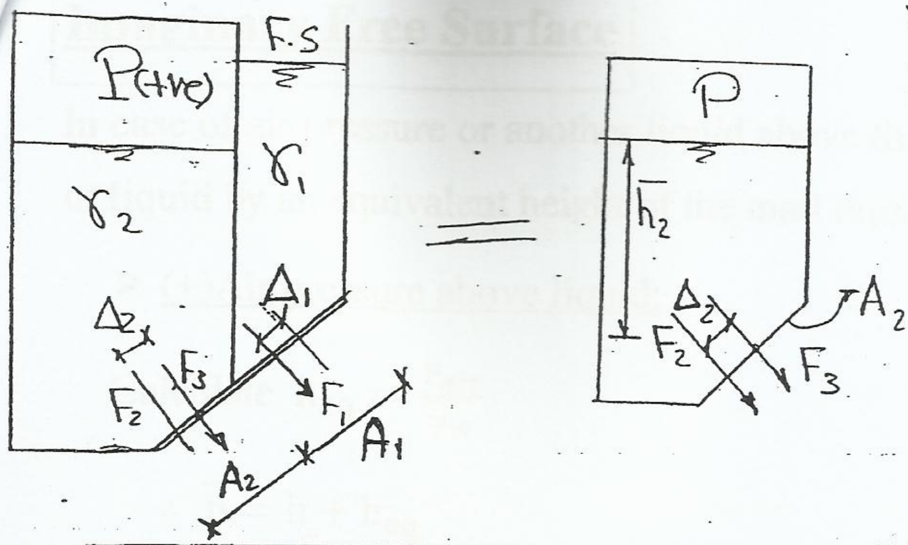
If F1 is –ve (in case of –ve air pressure) $\rightarrow$ $\left[\begin{array}{l} Z > \Delta \\ F_1 > F_2 \end{array}\right]$



$[F_1 < F_2]$



5) Separated two liquids:



$$F_1 = \gamma A_1 \bar{h}_1$$

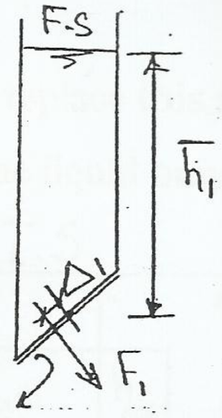
$$F_2 = \gamma A_2 \bar{h}_2$$

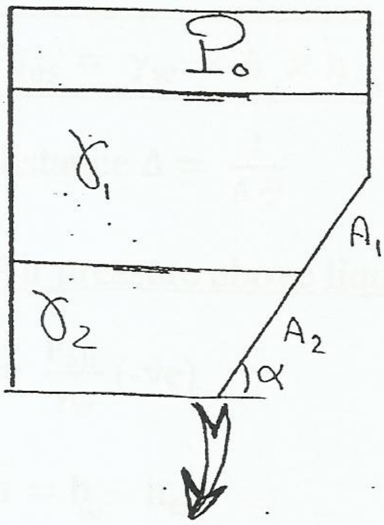
$$F_3 = P A_2$$

$$+$$

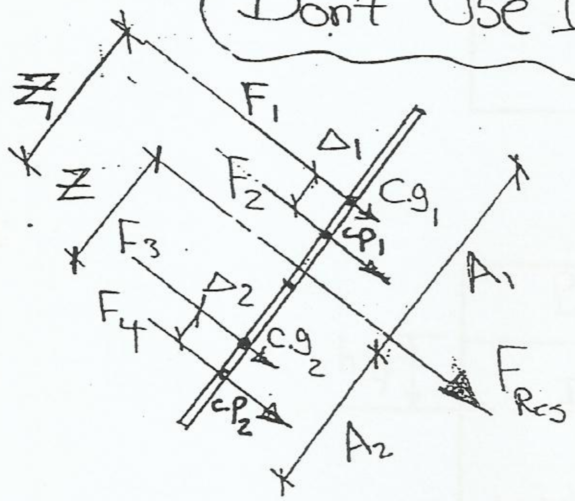
$$\Delta_1 = \frac{I_1}{A_1 \bar{y}_1}$$

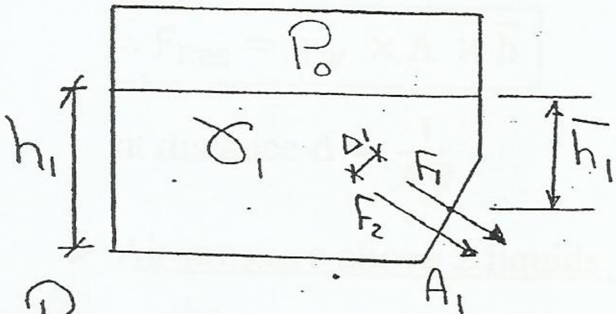
$$\Delta_2 = \frac{I_2}{A_2 \bar{y}_2}$$



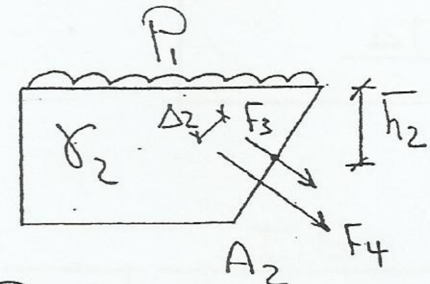


Don't Use Imaginary Surface





$$+$$



P_o = given $\rightarrow F_1 = P_o A_1$

$$F_2 = \gamma_1 A_1 \bar{h}_1 \qquad \Delta_1 = \frac{I_1}{A_1 \bar{y}_1}$$

$$\bar{y}_1 = \frac{\bar{h}_1}{\sin\alpha}$$

$$P_1 = P_o + \gamma_1 h_1$$

$$F_3 = P_1 A_2$$

$$F_2 = \gamma_2 A_2 \bar{h}_2 \qquad \Delta_2 = \frac{I_2}{A_2 \bar{y}_2}$$

$$\bar{y}_2 = \frac{\bar{h}_2}{\sin\alpha}$$

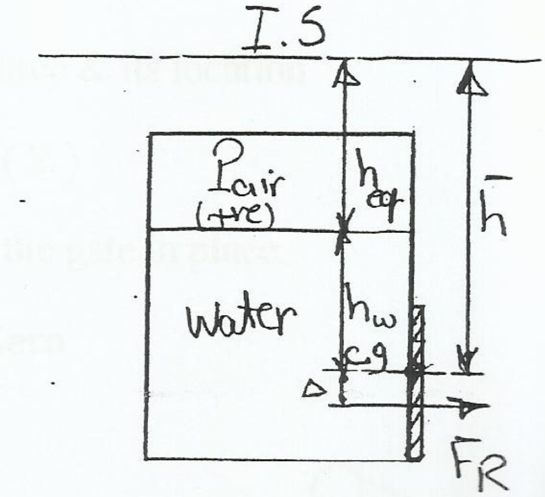
$$\therefore F_{res} = F_1 + F_2 + F_3 + F_4$$

To get (Z) --- $\Sigma M @ c.p_2 = 0$

Imaginary Free Surface

In case of air pressure or another liquid above the main liquid, we replace this air or liquid by an equivalent height of the mail liquid and solve for one liquid only.

- **(+)Air pressure above liquid:**



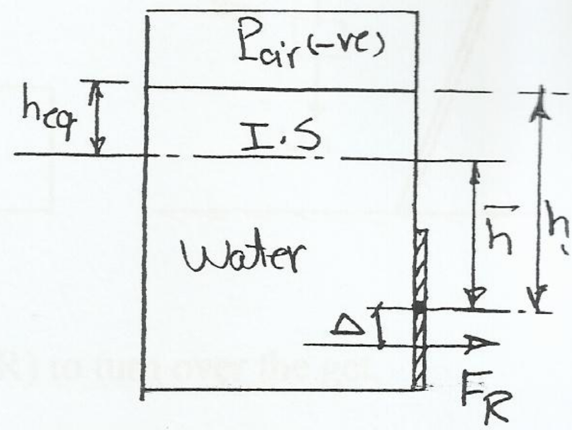
Calculate $h_{eq} = \frac{P_{air}}{\gamma_w}$

$\therefore \bar{h} = h_{\omega} + h_{eq}$

$$\boxed{\therefore F_{Res} = \gamma_w \times A \times \bar{h}}$$

at distance $\Delta = \frac{I}{A \cdot \bar{y}}$

- **(-)Air pressure above liquid:**



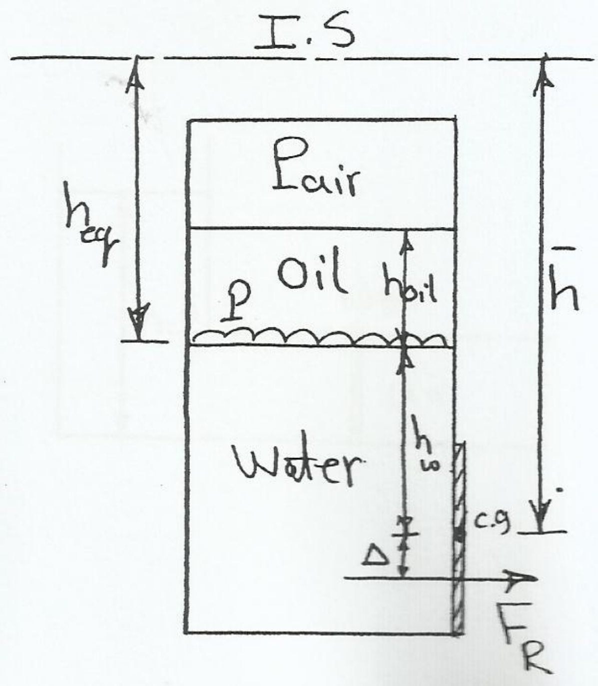
$h_{eq} = \frac{P_{air}}{\gamma_w}$ (-ve)

$\therefore \bar{h} = h_{\omega} - h_{eq}$

$$\boxed{\therefore F_{Res} = \gamma_w \times A \times \bar{h}}$$

at distance $\Delta = \frac{I}{A \cdot \bar{y}}$

- **Air pressure above 2 liquids:**



Calculate $P = P_{air} + \gamma_{oil} \times h_{oil}$

$\longrightarrow h_{eq} = \frac{P}{\gamma_w}$

$\therefore \bar{h} = h_{\omega} + h_{eq}$

$$\boxed{\therefore F_{Res} = \gamma_w \times A \times \bar{h}}$$

at distance $\Delta = \frac{I}{A \cdot \bar{y}}$

What is required in problems?

1. Forces acting on surface (gate)

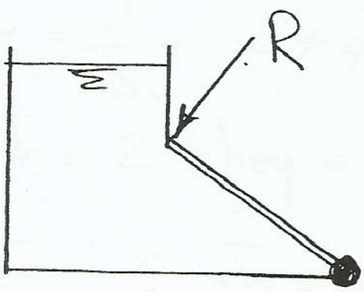
   → get (F) & no need for (Δ)

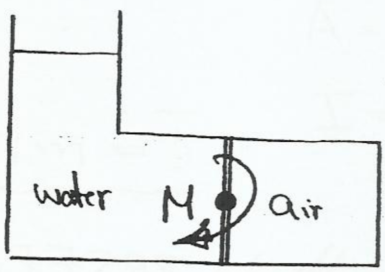
2. Force and line of action (OR) The resultant force & its location

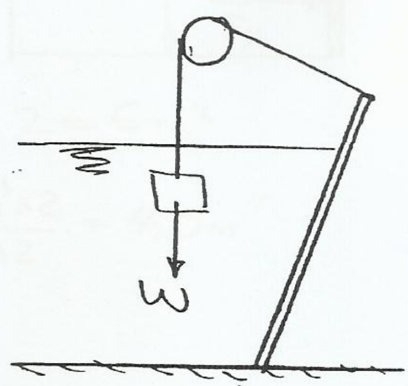
   → get (F) & (Δ) → $F_{res} = \sum F$ & get (Z)

3. The force, moment or weight required to hold the gate in place.

   → get (F) & (Δ) → $\sum M$ @ hinge = Zero

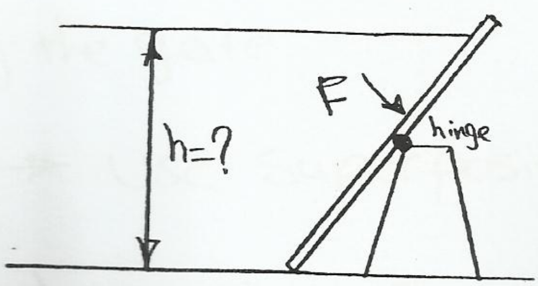


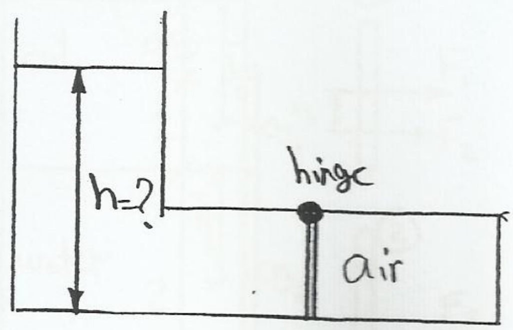




4. The liquid height required to hold the gate (OR) to turn over the get.

   → $\sum M$ @ hinge = Zero → get (F) & (Δ) → get (h).





get h to make the gate move

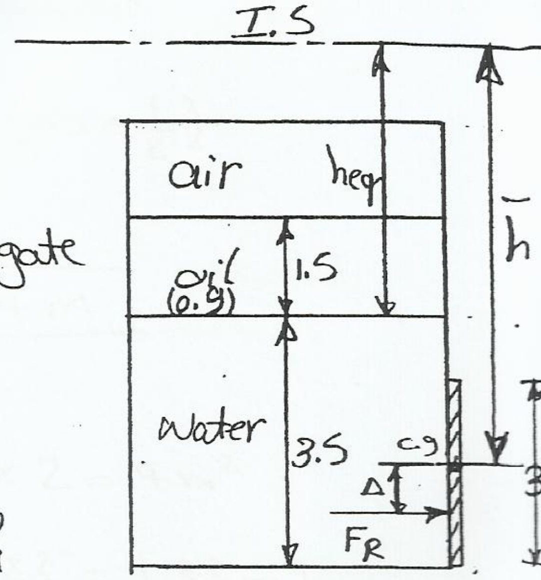
Ex.(1):

Find the resultant force and its point of application on the shown gate, giving that the air pressure is 30 kPa, for the following cases:

a. The water height is 3.5 m

b. The water height is 2 m

$b_{gate} = 2m$



Case (a) water surface is above the gate

$\therefore$ Use imaginary surface

$P = P_{air} + \gamma_o * h_o$

$= 30 \times 10^3 + (0.9 \times 9810) * 1.5 = 43243.5 \; Pa$

$\therefore h_{eq} = \frac{P}{\gamma_w} = 4.41 \; m$

$A = 3 \times 2 = 6 m^2$

$\hookrightarrow \bar{h} = 2 + h_{eq} = 6.41 m = \bar{y}$

$I = \frac{(3)^3 \times 2}{12} = 4.5 m^4$

$\therefore F_R = \gamma_w * \bar{h} * A = 377293 \; N$ #

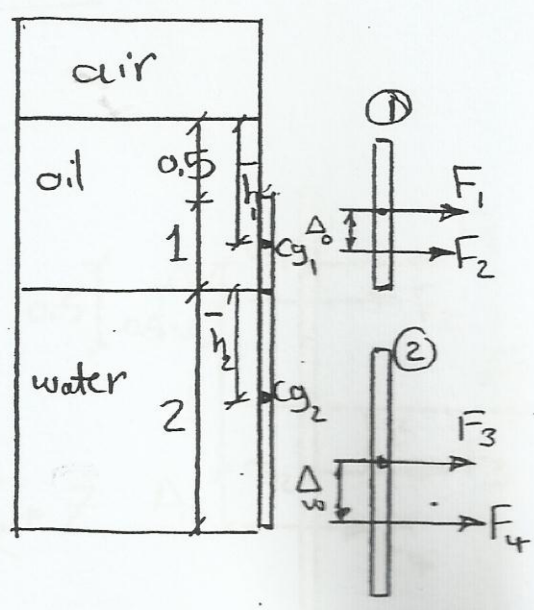
at $\Delta = \frac{I}{A\bar{y}} = 0.117 \; m$ #

Case (b)

water surface is below the top of the gate

$\hookrightarrow$ use superposition

& there will be 2 parts of the gate



* For part ① [oil] $A_1 = 1 \times 2 = 2 m^2$

$I_1 = \frac{(1)^3 \times 2}{12} = 0.167 m^4$

air $\rightarrow$ $F_1 = P_{air} * A_1 = \boxed{60{,}000 \; N \text{ at } C.g_{①}}$

oil $\rightarrow$ $F_2 = \gamma_o A_1 \bar{h}_1 = (0.9 * 9810) * 2 * (0.5 + \frac{1}{2})$

$= \boxed{17658 \; N}$

at $\Delta_o = \frac{I_1}{A_1 \bar{y}_1} = \frac{0.167}{2 * 1} = \boxed{0.084 m}$

* For part ② [water] $A_2 = 2 \times 2 = 4 m^2$

$I_2 = \frac{(2)^3 \times 2}{12} = 1.33 m^4$

oil+air $\rightarrow$ $P = P_{air} + \gamma_o h_o = 43243.5 \; Pa$

$\therefore F_3 = P * A_2 = \boxed{172974 \; N}$ at $C.g_{②}$

water $\rightarrow$ $F_4 = \gamma_w A_2 \bar{h}_2$

$= 9810 * 4 * \frac{2}{2} = \boxed{39240 \; N}$

at $\Delta_w = \frac{I_2}{A_2 \bar{y}_2} = \frac{1.33}{4 * 1} = \boxed{0.333 m}$

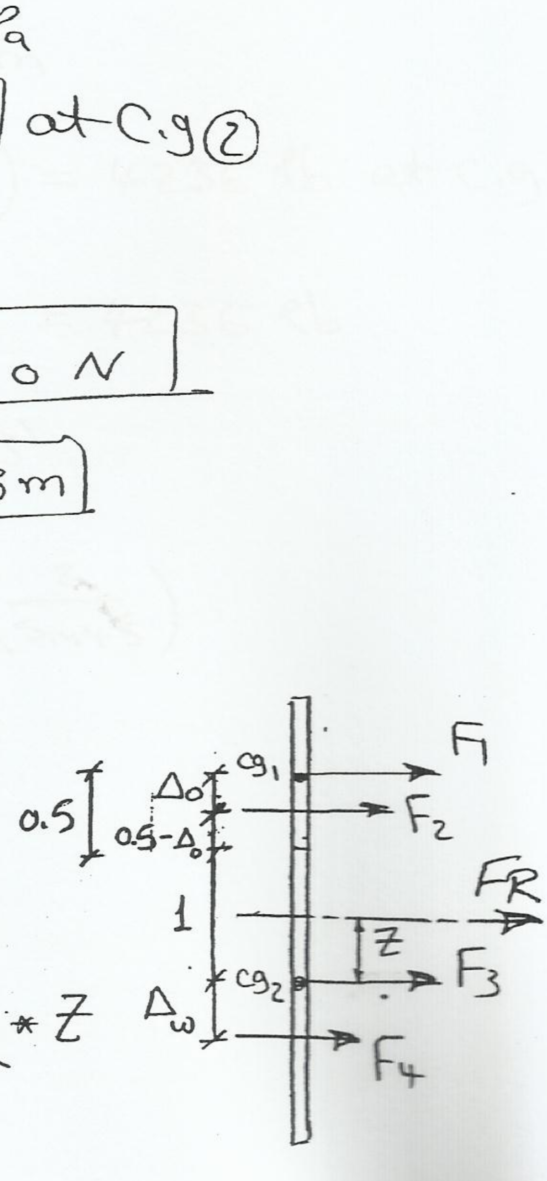
$\therefore F_R = \Sigma F = \boxed{289872 \; N}$

To get point of application

$\Sigma M \text{ @ } c.g_{②} = 0$

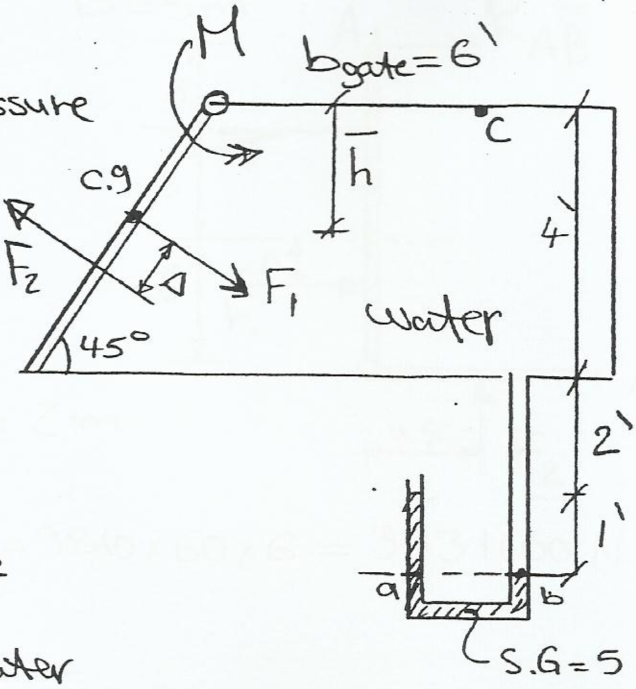
$F_1 * 1.5 + F_2 (1.5 - \Delta_o) - F_4 * \Delta_w = F_R * Z$

$\hookrightarrow$ get (Z)



Ex.(2):

Find the moment (M) required to hold the gate closed in the shown figure.



* First we have to Calculate the Pressure at the top of the water

$$P_a = P_b$$

$$5\gamma_w * 1 = P_c + \gamma_w * 7$$

$$\hookrightarrow P_c = -2\overset{62.4}{\gamma_w} = -124.8 \ lb/ft^2$$

Due to (-ve) Pressure above water

↳ use Super position

$$F_1 = P_c * A = 124.8 \left(\frac{4}{\sin 45} * 6\right) = 4236 \text{ lb at c.g}$$

$$F_2 = \gamma A \bar{h} = 62.4 \left(\frac{4}{\sin 45} * 6\right) * 2 = 4236 \text{ lb}$$

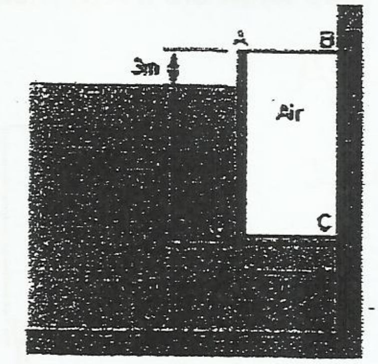
$$\text{at } \Delta = \frac{I}{A\bar{y}} = \frac{90.51}{33.9 * \frac{2}{\sin 45}} = 0.943'$$

$$\text{\& } M = F_2 * \left(\frac{2}{\sin 45} + \Delta\right) - F_1 * \left(\frac{2}{\sin 45}\right)$$

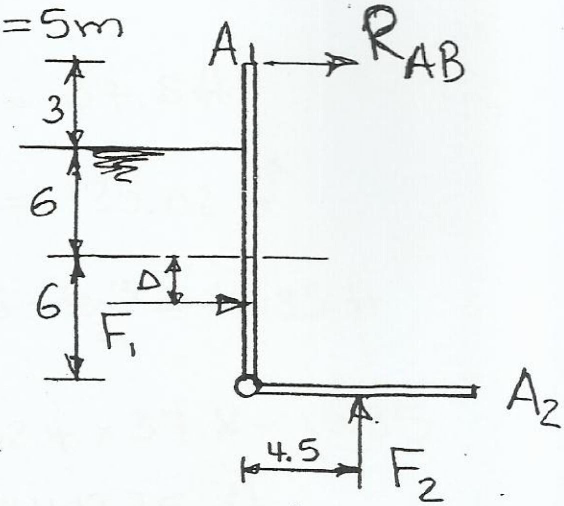
$$= \boxed{3993 \text{ lb.ft}}$$

*3/1-21 Gate *AOC* shown is 5m wide and is hinged along O (*i.e., it can rotate freely about axis o*). Neglecting the weight of the gate, determine the force in bar *AB*.

Req :- R_{AB}



$b = 5m$



Solution :-

$A_1 = 12 \times 5 = 60\, m^2$

$I_1 = 5(12)^3/12 = 720\, m^4$

$\bar{h} = \bar{y} = 6\, m$

$\Delta = \frac{I}{A\bar{y}} = 2\, m$

$F_1 = \gamma A_1 \bar{h}_1 = 9810 \times 60 \times 6 = 3531600\, N$

$A_2 = 9 \times 5 = 45\, m^2$

$I_2 = 5(9)^3/12 = 303.75\, m^4$

$\bar{h}_2 = 12$

$F_2 = \gamma A_2 \bar{h}_2$

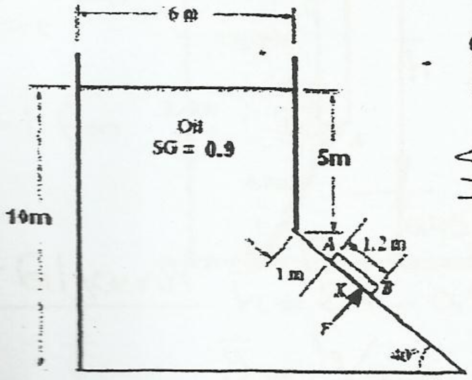
$= 9810 \times 45 \times 12 = 5297400\, N$

$\Delta_2 = 0$ (F_2 at center)

$\Sigma M @ hinge = Zero \Rightarrow R_{AB} \times 15 + F_1(6 - \Delta) = F_2 \times 4.5$

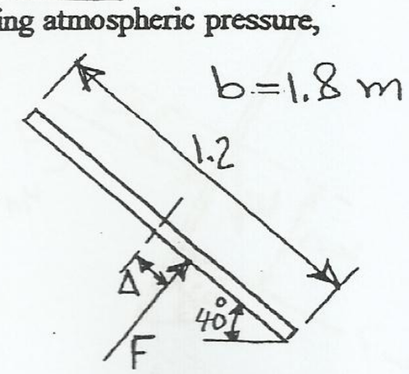
$\hookrightarrow \boxed{R_{AB} = 647460\, N}$

3/1-22 Gate *AB* in Fig. is 1.2 m long and 1.8 m into the paper. Neglecting atmospheric pressure, compute the force *F* on the gate and its center-of-pressure position *X*.



Req :- F & Δ

$b = 1.8\, m$



Sol :-

$A = 1.2 \times 1.8 = 2.16\, m^2$

$I = \frac{(1.2)^3 \times 1.8}{12} = 0.259\, m^4$

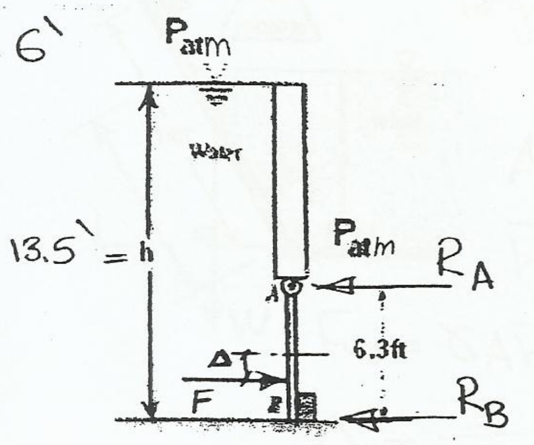
$\bar{h} = 5 + 1.6 \sin 40 = 6.03\, m \quad \bar{y} = \bar{h}/\sin 40 = 9.38\, m$

$F = \gamma_{oil} A \bar{h} = (9810 \times 0.9) \times 2.16 \times 6.03 = \boxed{114995.95\, N}$

$\Delta = \frac{I}{A\bar{y}} = \boxed{0.013\, m}$

✓ **3/1-23** Gate *AB* in Fig. is 6 ft wide into the paper, hinged at *A*, and restrained by a stop at *B*. The water is at 25° C. Compute
(*a*) The force on stop *B*
(*b*) The reactions at *A* if the water depth *h* = 13.5 ft.

$b = 6'$



$$A = 6 \times 6.3 = 37.8\ ft^2$$

$$I = \frac{6\,(6.3)^3}{12} = 125.02\ ft^4$$

$$\bar{h} = \bar{y} = 13.5 - \frac{6.3}{2} = 10.35\ ft$$

$$F = \gamma A \bar{h} = 62.4 * 37.8 * 10.35$$
$$= 24412.75\ lb$$

$$\Delta = \frac{I}{A\bar{y}} = 0.32\ ft$$

ΣM @ hinge = Zero

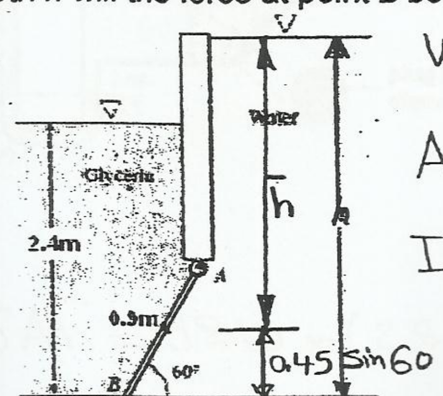
$\rightarrow F\left(\frac{6.3}{2} + \Delta\right) = R_B * 6.3 \Rightarrow \boxed{R_B = 13446.4\ lb}$

$\Sigma F_x = 0 \rightarrow R_A + R_B = F \Rightarrow \boxed{R_A = 10966.4\ lb}$

3/1-24 Gate *AB* in Fig. is a homogeneous mass of 280 kg, 1.6 m wide into the paper, hinged at *A*, and resting on a smooth bottom at *B*. All fluids are at 26° C. For what water depth *h* will the force at point *B* be zero?

From tables $(S.G) = 1.26$ glycerine

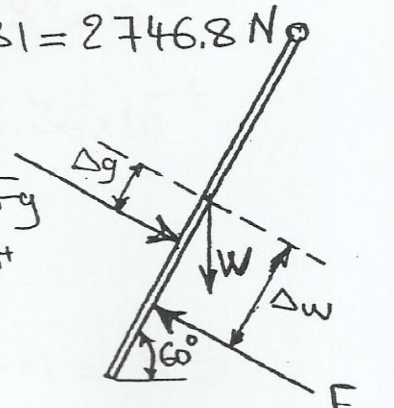
$b = 1.6m$



$$W_{gate} = m \times g = 280 \times 9.81 = 2746.8\ N$$

$$A = 0.9 \times 1.6 = 1.44\ m^2$$

$$I = \frac{(0.9)^3 \times 1.6}{12} = 0.097\ m^4$$



For Glycerin

$$\bar{h} = 2.4 - 0.45\sin 60 = 2.01\ m$$

$$\bar{y} = \bar{h}/\sin 60 = 2.32\ m$$

$$F_g = \gamma_g A \bar{h} = (1.26 \times 9810) * 1.44 * 2.01 = 35776.5\ N$$

$$\Delta_g = I/A\bar{y} = 0.029\ m$$

For Water

$$F_w = \gamma_w A \bar{h} = 14126.4\,\bar{h} \quad \Delta = \frac{I}{A\bar{y}} = \frac{0.058}{\bar{h}}$$

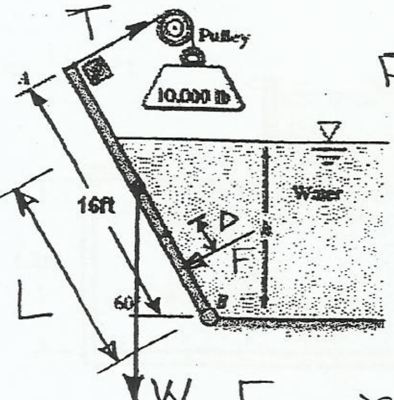
ΣM@hinge =

$$\boxed{F_g(0.45 + \Delta_g) - F_w(0.45 + \Delta_w) + W(0.45\ \cos 60°) = 0}$$

$\rightarrow \boxed{\bar{h} = 2.66\ m}$

3/1-25 Gate *AB* in Fig. is 15 ft long and 9 ft wide into the paper and is hinged at *B* with a stop at *A*. The water is at 12^0 C. The gate is 0.9-in-thick steel, SG =7.85. Compute the water level *h* for which the gate will start to fall.

$b = 9'$



$T = 10{,}000\ lb$

For gate $W = \forall * \gamma_{st} = (16 * 9 * \frac{0.9}{12}) * 7.85 * 62.4$

$= 5290.27\ lb$

$A = (9L)\ ft^2 \quad I = \frac{9L^3}{12} = (0.75L^3)\ ft^4$

$\bar{h} = \frac{h}{2} \quad \bar{y} = \frac{\bar{h}}{\sin 60} = \frac{h}{2\sin 60} \quad * \quad L = \frac{h}{\sin 60}$

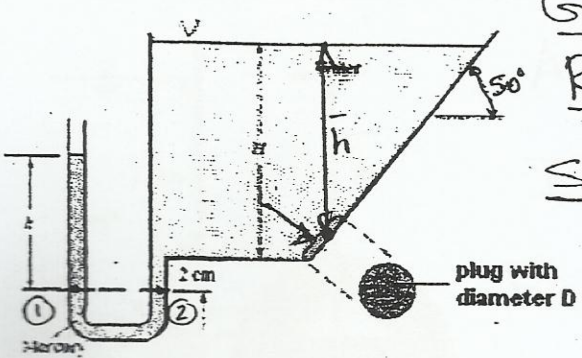
$F_w = \gamma A \bar{h} = 62.4 * 9L * h/2 = 324.24h$

$\Delta = \frac{I}{A\bar{y}} = \frac{0.75L^3}{9L * L/2} = 0.167L = 0.192h$

$\Sigma M @ B = 0$

$T * 16 = W * 8\cos 60 + F\left(\frac{h}{2\sin 60} - \Delta\right) \longrightarrow \boxed{h = 33.33\ m}$

3/1-26 The tank in Fig. has a 6-cm-diameter plug at the bottom on the right. All fluids are at 20^0 C. The plug will pop out if the hydrostatic force on it is 45 N. For this condition, what will be the reading *h* on the mercury manometer on the left side?



Given $D = 6cm \quad F = 45\ N$

Req Manometer reading (h)

Sol:- $A = \frac{\pi D^2}{4} = 2.83 * 10^{-3}$

$I = \frac{\pi D^4}{64} = 6.36 \times 10^{-7}$

$\bar{y} = \frac{\bar{h}}{\sin 50}$

$F = \gamma A \bar{h} = 9810 * (2.83 \times 10^{-3}) * \bar{h} = 27.76\bar{h} = 45$

$\hookrightarrow \bar{h} = 1.62 \rightarrow H = \bar{h} + 0.03 \sin 50 = 1.644\ m$

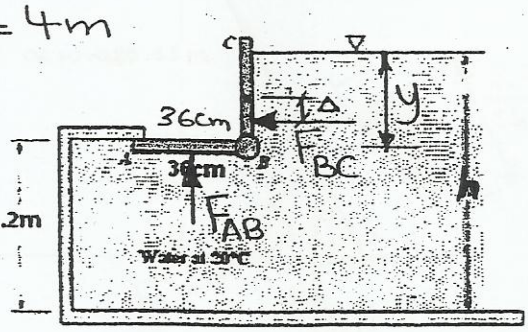
In manometer:-

$P_1 = P_2$

$\gamma_{Hg} * h = \gamma_w * (H + 0.02) \longrightarrow \boxed{h = 0.122\ m}$

✓ **3/1-27** Gate *ABC* in Fig. has a fixed hinge line at *B* and is 4 m wide into the paper. The gate will open at *A* to release water if the water depth is high enough. Compute the depth *h* for which the gate will begin to open.

$b = 4m$



Part AB

$A = 0.36 * 4 = 1.44 m^2$

$I = \frac{(0.36)^3 * 4}{12} = 0.016 m^4$

$\bar{h} = \bar{y} = y$

$\therefore F_{AB} = \gamma_w A \bar{h} = 1.44 \gamma_w y$ at c.g

Part BC

$A = 4y \quad I = \frac{4y^3}{12} = 0.33y^3$

$\bar{h} = \bar{y} = y/2$

$F_{BC} = \gamma A \bar{h} = 2\gamma_w y^2$

$\Delta = I/A\bar{y} = y/6$

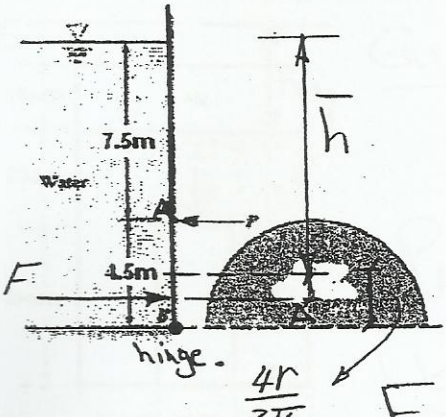
$\Sigma M @ B = 0$

$F_{AB} * 0.18 = F_{BC}\left(\frac{y}{2} - \Delta\right)$

$\therefore 1.44 \cancel{\gamma_w} y * 0.18 = 2 \cancel{\gamma_w} y^2 \left(\frac{y}{2} - \frac{y}{6}\right)$

$\hookrightarrow y = 0.624 \rightarrow h = y + 1.2 = \boxed{1.824 m}$

3/1-28 Gate *AB* in Fig. is semicircular, hinged at *B*, and held by a horizontal force *P* at *A*. What force *P* is required for equilibrium T = 12° C?



$A = \frac{\pi (4.5)^2}{2} = 31.81 m^2$

$I = 0.11(4.5)^4 = 45.11 m^4$

$\bar{h} = \bar{y} = 12 - \frac{4(4.5)}{3\pi} = 10.09 m$

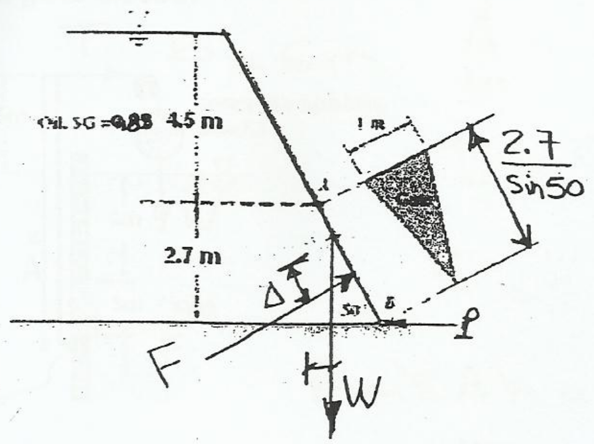
$F = \gamma A \bar{h} = 3148690 N$

$\Delta = \frac{I}{A\bar{y}} = 0.141 m$

$\Sigma M @ B = 0$

$P * 4.5 - F\left(\frac{4(4.5)}{3\pi} - \Delta\right) = 0 \rightarrow \boxed{P = 1237687 N}$

3/1-29 Isosceles triangle gate *AB* in Fig. is hinged at *A* and weighs 2350 N. What horizontal force *P* is required at point *B* for equilibrium?



$$A = \frac{2.7}{\sin 50} * 1 * 0.5 = 1.76\ m^2$$

$$I = \frac{1}{36}\left(\frac{2.7}{\sin 50}\right)^3 = 1.22\ m^4$$

$$\bar{h} = 4.5 + \frac{2.7}{3} = 5.4\ m$$

$$\bar{y} = \frac{\bar{h}}{\sin 50} = 7.05\ m$$

$$F = \gamma A \bar{h} = (0.83 * 9810) * 1.76 * 5.4 = 77384.4\ N$$

$$\Delta = \frac{I}{A\bar{y}} = 0.098\ m$$

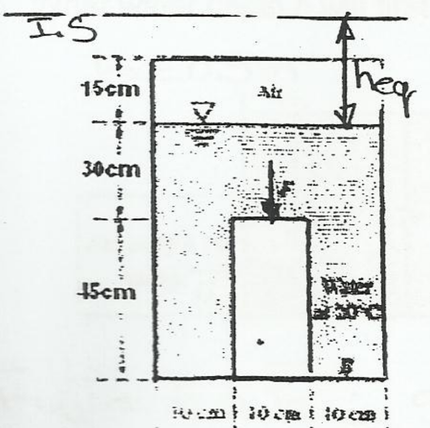
$$\boxed{P = 35824 N}$$

$$\Sigma M @ A = 0 \rightarrow P * 2.7 + \overset{2350}{W}\left(\frac{2.7}{3} / \tan 50\right) - F\left(\frac{2.7}{3\sin 50} + \Delta\right) = 0$$

3/1-30 The cylindrical tank in Fig. has a 45-cm-high cylindrical insert in the bottom. The pressure at point *B* is 265 k Pa. Find:

(*a*) The pressure in the air space?

(*b*) The force *F* on top of the insert? (Neglect air pressure outside the tank)



Given $P_B = 265\ KPa$

$$A = \frac{(0.1)^2}{4}\pi = 7.85 \times 10^{-3}\ m^2$$

$$P_{Air} = P_B - \gamma_w (0.75) = 257643\ Pa$$

Using Superposition

$$F_{air} = P_{air} * A = 2022.5\ N$$

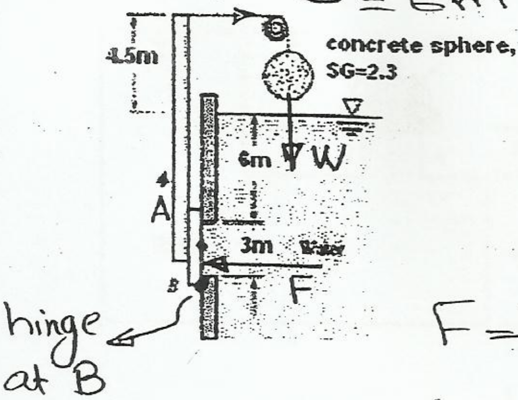
$$F_{water} = \gamma A \bar{h} = 9810 * (7.85 \times 10^{-3}) * 0.3 = 23.1\ N$$

$$\rightarrow F_{Total} = F_{air} + F_{water} = \boxed{2045.6\ N}$$

Using Imaginary Surface $h_{eq} = \frac{P_{air}}{\gamma_w} = 26.26\ m$

$$\bar{h} = h_{eq} + 0.3 = 26.56 \rightarrow F_{Total} = \gamma A \bar{h} = \boxed{2045.6\ N}$$

3/1-31 In Fig. gate *AB* is 6 m wide into the paper and is connected by a rod and pulley to a concrete sphere (SG = 2.3). What diameter of the sphere is just sufficient to keep the gate closed?



$b = 6m$

$A_{gate} = 3*6 = 18 m^2$

$I = \frac{(3)^3*6}{12} = 13.5 m^4$

$\bar{h} = \bar{y} = 6 + \frac{3}{2} = 7.5m$

$F = \gamma A \bar{h} = 1324350 N$

$\Delta = \frac{I}{A\bar{y}} = 0.1 m$

$\Sigma M @ B = 0 \longrightarrow T * 13.5 = F * (1.5 - \Delta)$

$\hookrightarrow T = 137340$

But $W = T = \gamma_{Conc} * \forall \rightarrow \forall = \frac{137340}{2.3*9810} = 6.09 m^3$

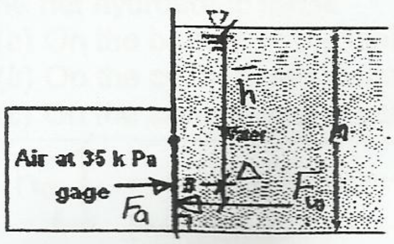
$\forall = \frac{4}{3}\pi r^3$

$\therefore r = 1.13 m$

$\boxed{\therefore D = 2.26 m}$

3/-32 Gate *B* in Fig. is 60 cm high, 90 cm wide into the paper, and hinged at the top. What water depth *h* will first cause the gate to open?

$b = 0.9m$



$A_{gate} = 0.6*0.9 = 0.54 m^2$

$I = \frac{(0.6)^3*0.9}{12} = 0.0162 m^4$

$\bar{h} = \bar{y}$

$F_w = \gamma A \bar{h} = 5297.4 \bar{h}$

$\Delta = \frac{I}{A\bar{y}} = \frac{0.03}{\bar{h}}$

$F_{air} = P_{air} * A$

$= 35*10^3 * 0.54$

$F_{air} = 64814.8$ N at cg

When the gate starts to open

$\Sigma M @ hinge = 0$

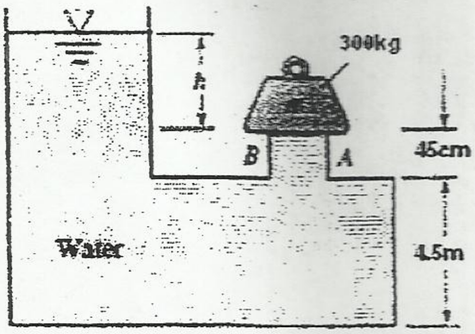
$F_{air} * 0.3 = F_w (0.3 + \Delta)$

$19444.4 = 5297.4 \bar{h} (0.3 + \frac{0.03}{\bar{h}})$

$\bar{h} = 12.14 m$

$\therefore h = \bar{h} + 0.3 = 12.44 m$

3/1-33 In Fig. The cover gate *AB* closes a circular opening 60 cm in diameter. The gate is held closed by a 300-kg mass as shown. Assume standard gravity at 27° C. At what water level *h* will the gate be dislodged? Neglect the weight of the gate.



$$A = \frac{\pi (0.6)^2}{4} = 0.283 \text{ m}^2$$

$$F_w = W = mg$$

$$\rightarrow \gamma_w A h = m * g$$

$$\rightarrow h = \frac{300 * 9.81}{0.283 * 9810} = \boxed{1.06 m}$$

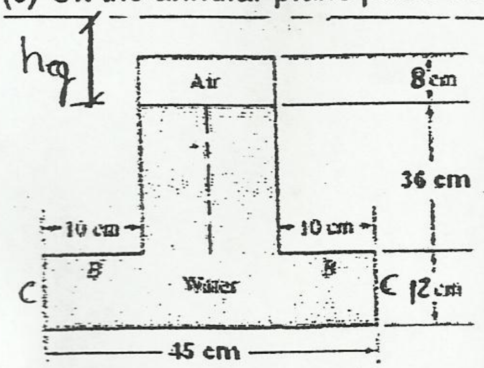
*4/1-34 Pressure in the air gap in Fig. is 11 k Pa gage. The tank is cylindrical. Calculate the net hydrostatic force:

(a) On the bottom of the tank

(b) On the cylindrical sidewall *CC*

(c) On the annular plane panel *BB*. I.S

$$h_{eq} = \frac{P_{air}}{\gamma_w} = 1.12 \text{ m}$$



(a) Force on bottom

$$A = \frac{\pi (0.45)^2}{4} = 0.159 \text{ m}^2$$

$$\bar{h} = h_{eq} + 0.48 = 1.6 \text{ m}$$

$$\therefore F_{Bottom} = \gamma A \bar{h} = 2495.7 \text{ N}$$

(b) On sidwall

$$A = 0.45 * 0.12 = 0.054 \text{ m}^2$$

$$\bar{h} = h_{eq} + 0.36 + 0.06 = 1.54 \text{ m}$$

$$F_{S.W} = 815.8 \text{ N}$$

(c) On plane BB

$$A = \frac{\pi}{4}(0.45^2 - 0.25^2) = 0.11 \text{ m}^2$$

$$\bar{h} = h_{eq} + 0.36 = 1.48 \text{ m}$$

$$F_{BB} = 1597 \text{ N}$$