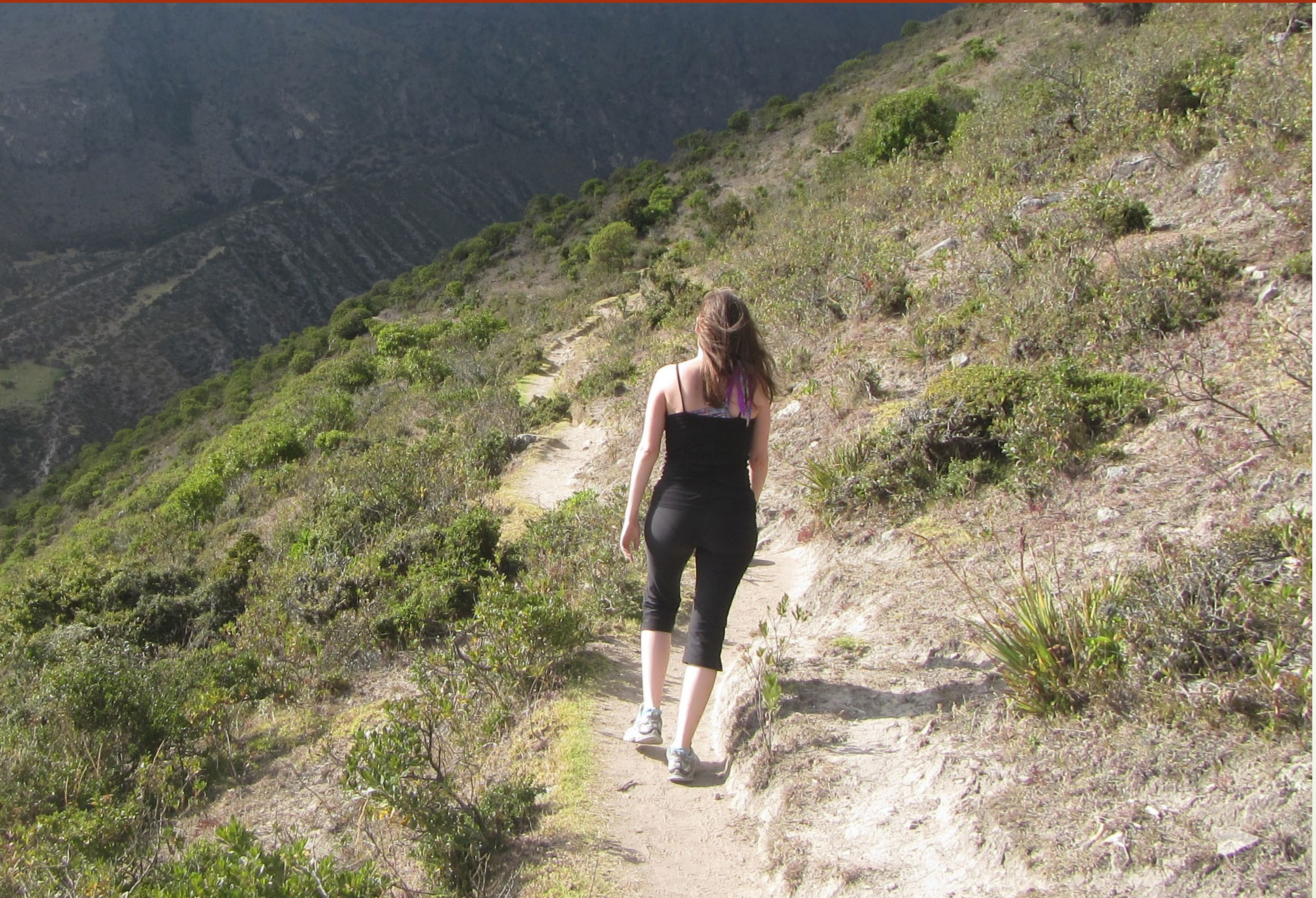
STUDY AID SUBMERGED Planar SURFACES

Fluid Mechanics

Dr. K. J Berry

FOLLOW THE PATH



- *Follow the path, follow the path, follow the path.*

Dr. Berry will not steer you wrong. He provides you with all the tools you need to complete this course, you just need to trust his process and use the tools provided to apply them to engineering problems.

MECH-420 Student, Spring 2021

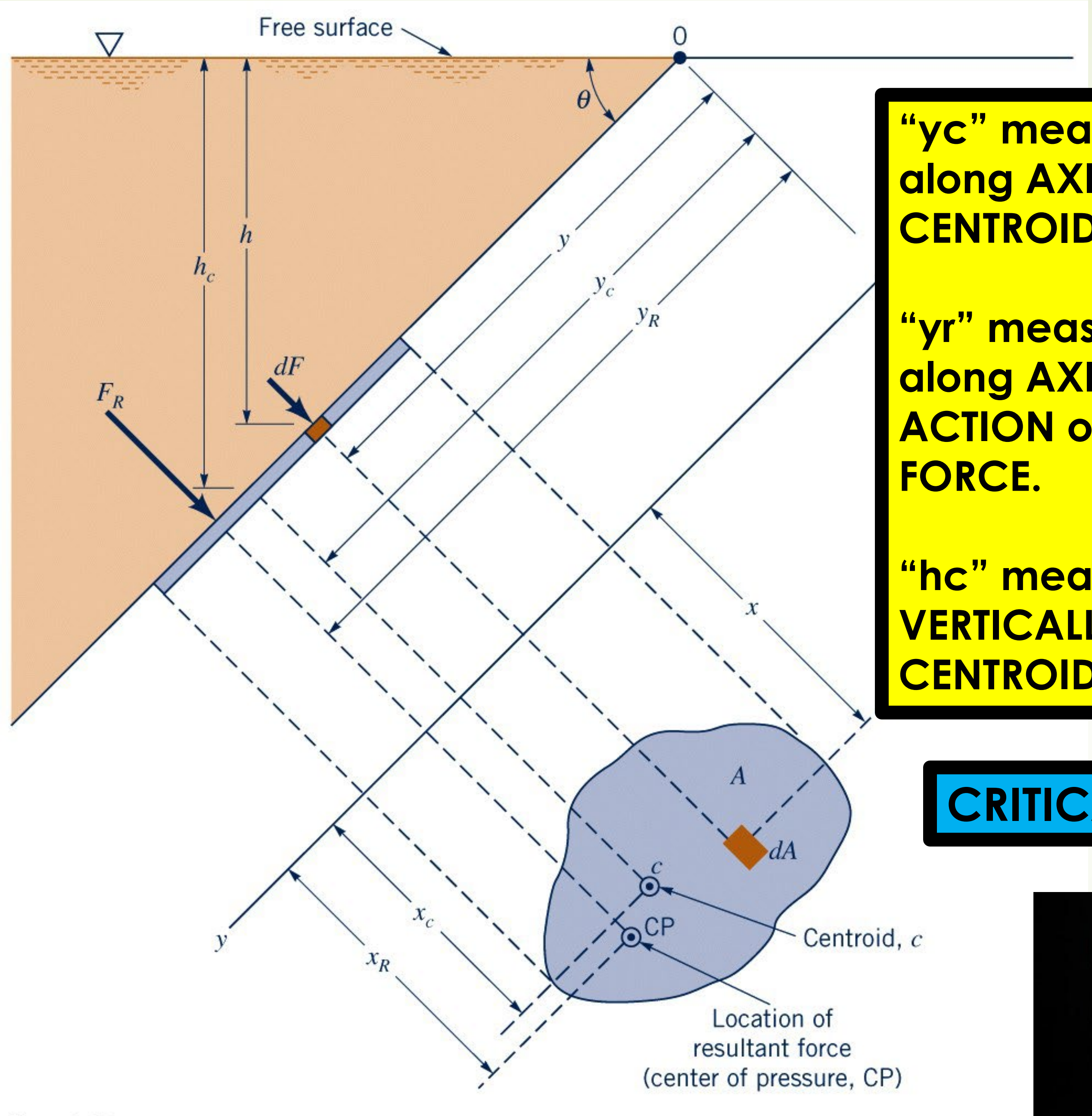


Figure 2.17

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“yc” measured from SURFACE along AXIS of plate to the plate CENTROID.

“yr” measured from SURFACE along AXIS of plate to LINE of ACTION of resultant pressure FORCE.

“hc” measured from SURFACE VERTICALLY to location of PLATE CENTROID.

CRITICAL DEFINITIONS

Consider the Submarine Hatch Below with seawater on the outside and air inside. The hatch weight is 280N How does the inner air pressure vary to "just open the hatch"?.

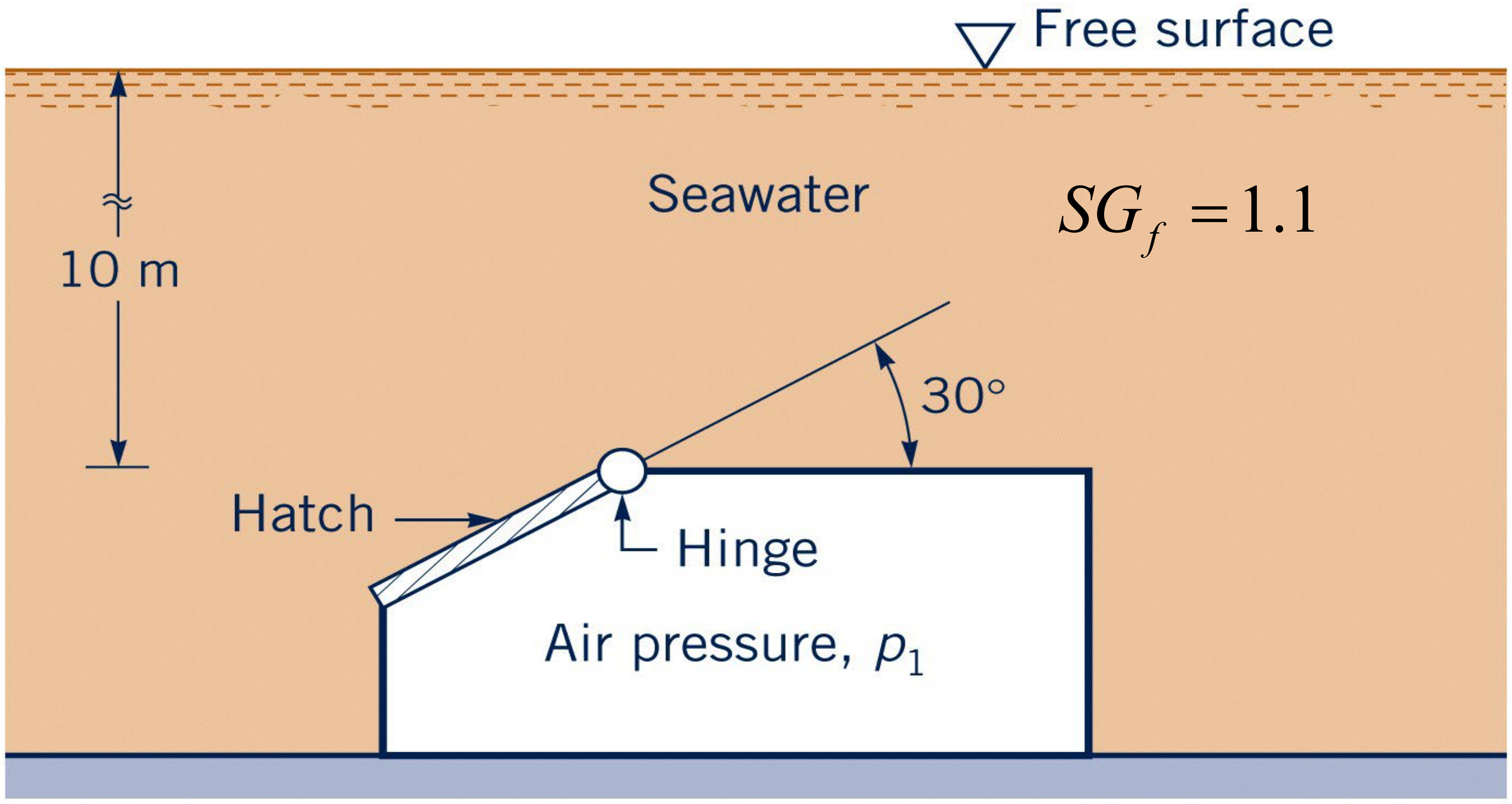

Figure P2.82

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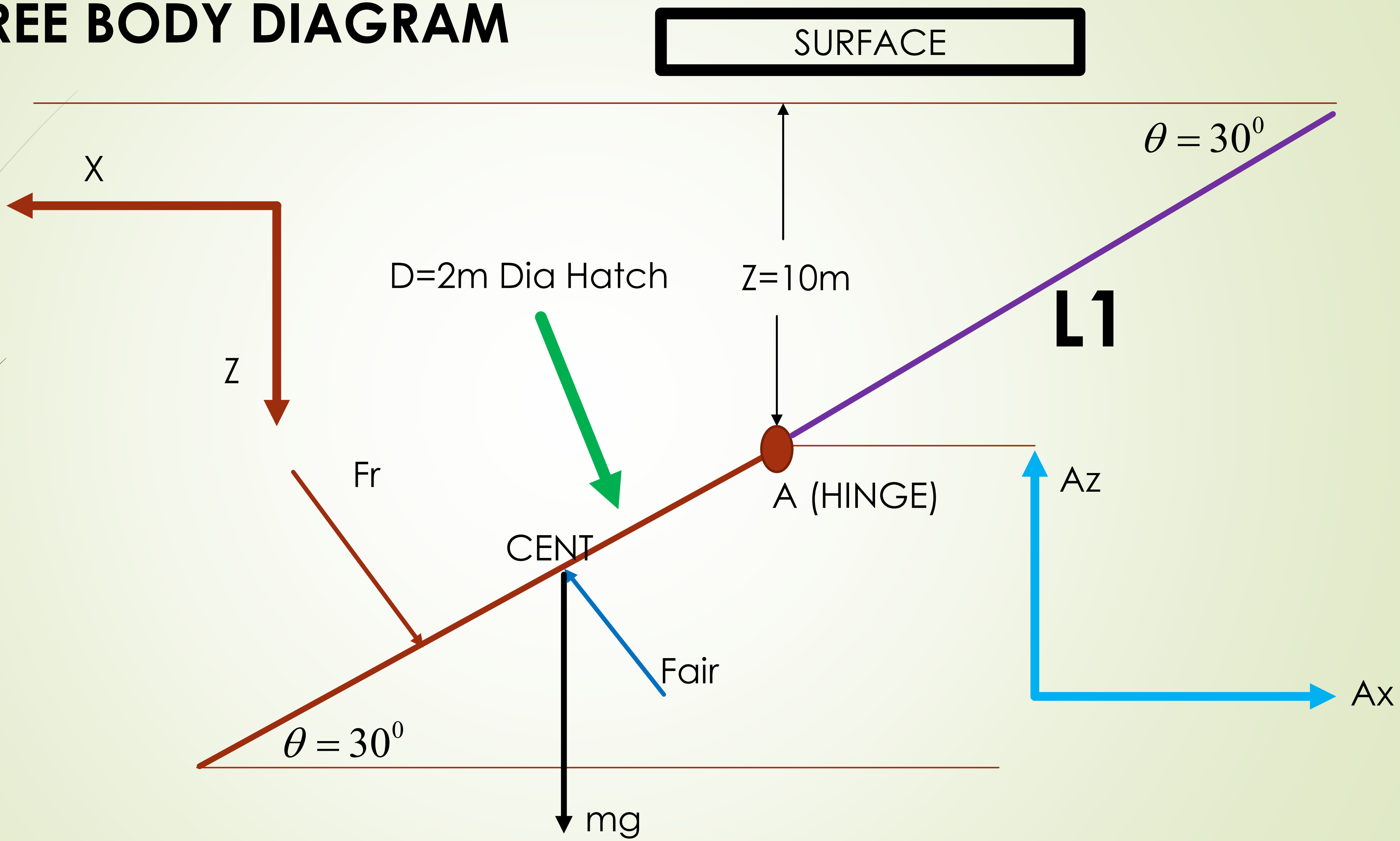
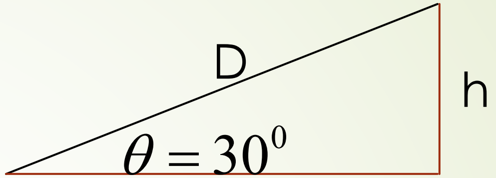
FREE BODY DIAGRAM



WATER PRESSURE RESULTANT FORCE

$$F_R = \gamma_f h_c \ A$$

$$y_r = y_c + \frac{I_{xxc}}{y_c A_p}$$



$$\sin\theta = \frac{h}{D}, D = 2m$$

$$h = D\sin\theta = 2m \bullet \sin 30 = 1m$$

$$h_c = Z + \frac{D\sin\theta}{2} \quad \text{(Vertical Distance to Centroid)}$$

$$= 10m + 0.5m = 10.5m$$

$$F_R = \gamma_f h_c \ A$$

$$= \gamma_f (10,780 \frac{N}{m^3}) \bullet \left(Z + \frac{D\sin\theta}{2}\right)\left(\frac{\pi D^2}{4}\right)$$

$$= 355,597 (79,938 lbf : \frac{1N}{0.2248 lbf})$$

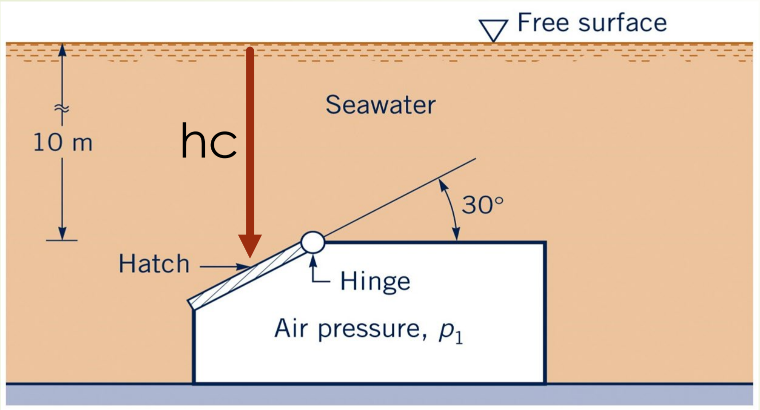


Figure P2.82

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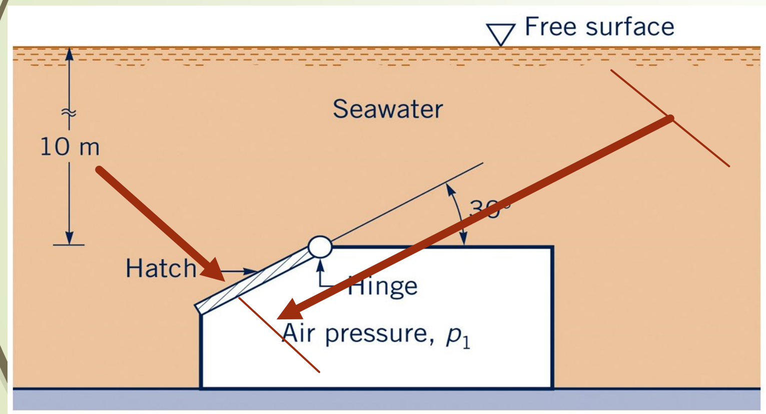
LINE OF ACTION

$$F_R = \gamma_f h_c A$$

$$y_r = y_c + \frac{I_{xxc}}{y_c A_p}$$



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$$\sin\theta = \frac{Z}{L_1} \rightarrow L_1 = \frac{Z(=10)m}{\sin\theta} = 20m \rightarrow \text{Parallel Distance to HINGE}$$

$$y_c = L_1 + \frac{D}{2} \rightarrow \text{Parallel Distance to CENTROID}$$

$$= \frac{Z}{\sin\theta} + \frac{D}{2} = 21m$$

$$I_{xxc} = \frac{\pi R^4}{4} = 0.7854m^4$$

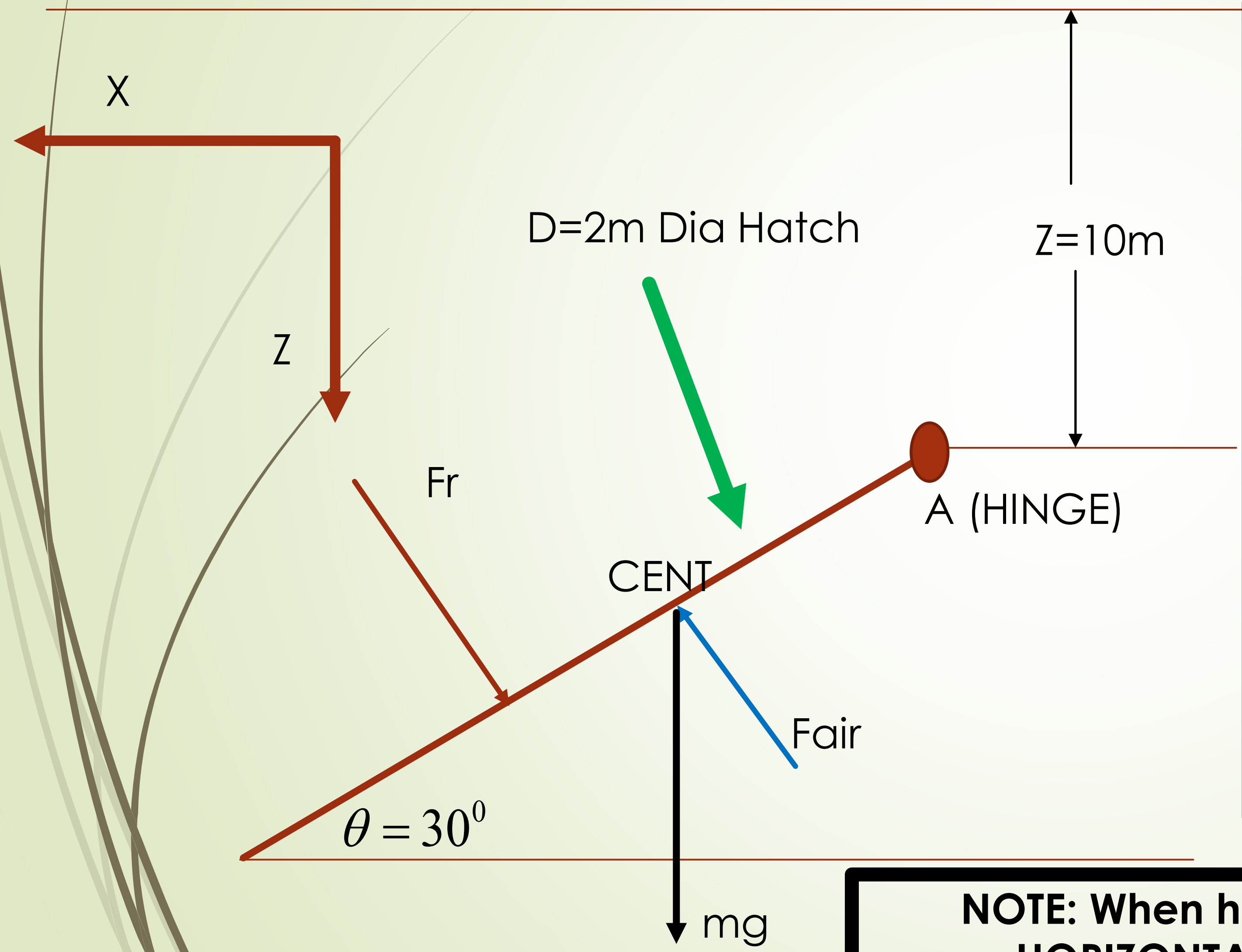
$$y_r = y_c + \frac{Ixc}{y_c A} \rightarrow \text{Parallel Distance to LINE OF ACTION}$$

$$= \left(\frac{Z}{\sin\theta} + \frac{D}{2}\right) + \frac{\frac{\pi R^4}{4}}{\left(\frac{Z}{\sin\theta} + \frac{D}{2}\right)\frac{\pi D^2}{4}}$$

$$= 21m + \frac{0.7854m^4}{21m \bullet 3.14159m^2}; D = 2m$$

$$= 21.012m$$

AIR PRESSURE ACTING AT CENTROID



$$\sum_{CCW+} M_A = 0$$

$$+F_r(y_r - L_1) + mg(\frac{D}{2}\cos\theta) - \left\{P_{air}\left[\frac{N}{m^2}\right]A_p\right\}\frac{D}{2} = 0$$

$$\frac{F_r(y_r - L_1) + mg(\frac{D}{2}\cos\theta)}{A_p\frac{D}{2}} = P_{air}$$

$$L_1 = \frac{Z(=10)m}{\sin\theta}$$

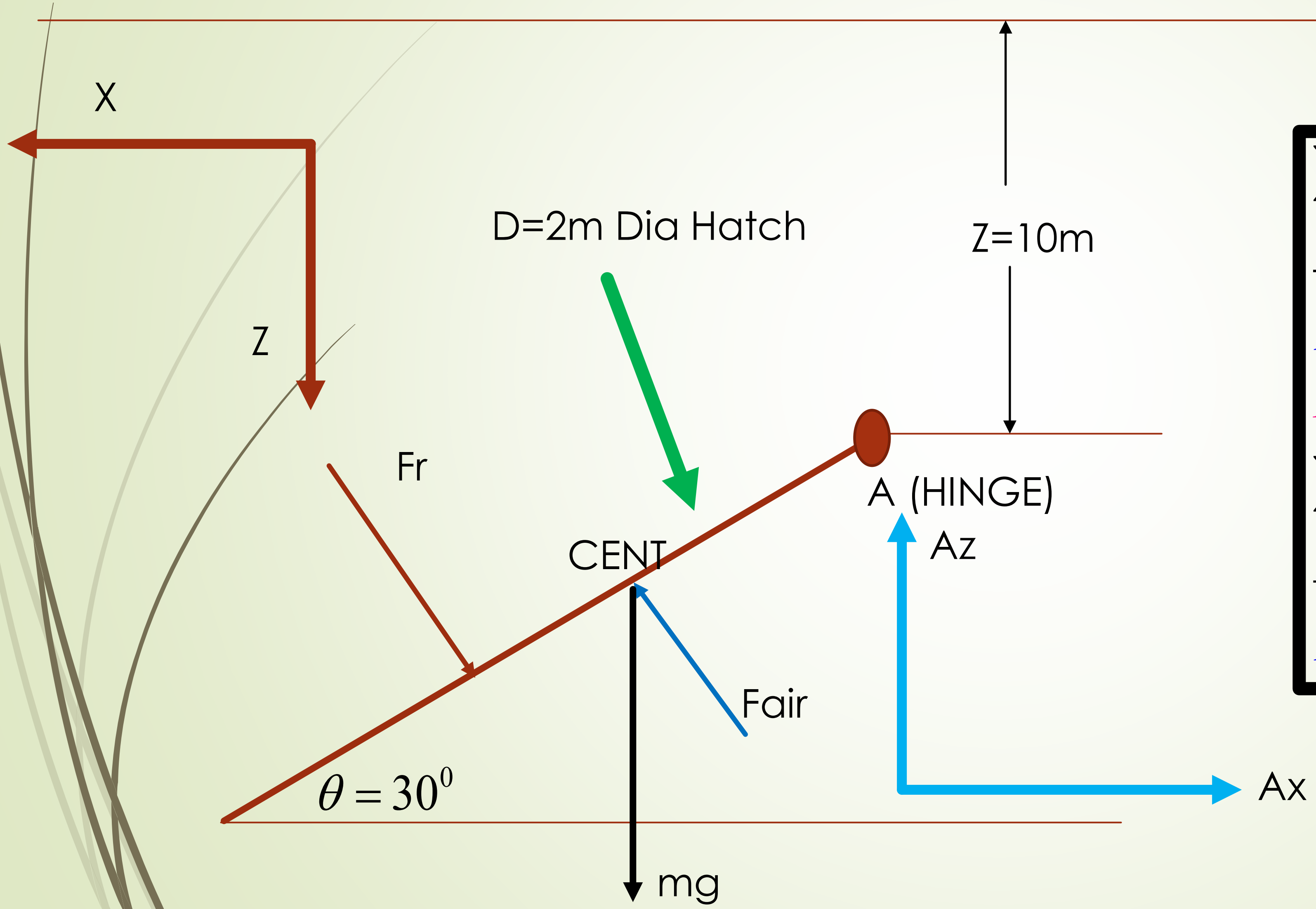
$$\frac{F_r(y_r - \frac{Z}{\sin\theta}) + mg(\frac{D}{2}\cos\theta)}{A_p\frac{D}{2}} = P_{air}(Z, mg, D, \theta)$$

NOTE: When hatch is just ready to open, there is NO HORIZONTAL FORCE from the internal structure

UNIT CHECK

$$\frac{F_r\left(y_r - \frac{Z}{\sin\theta}\right)[N-m] + mg\left(\frac{D}{2}\cos\theta\right)[N-m]}{A_p \frac{D}{2}[m^3]} = P_{air}\left[\frac{N}{m^2}\right](Z, mg, D, \theta)$$

HINGE REACTION FORCES



$$\sum_{\leftarrow} F_x = 0$$

$$-F_r \sin\theta - A_x + F_{air} \sin\theta = 0$$

$$A_x = \sin\theta (F_{air} - F_r)$$

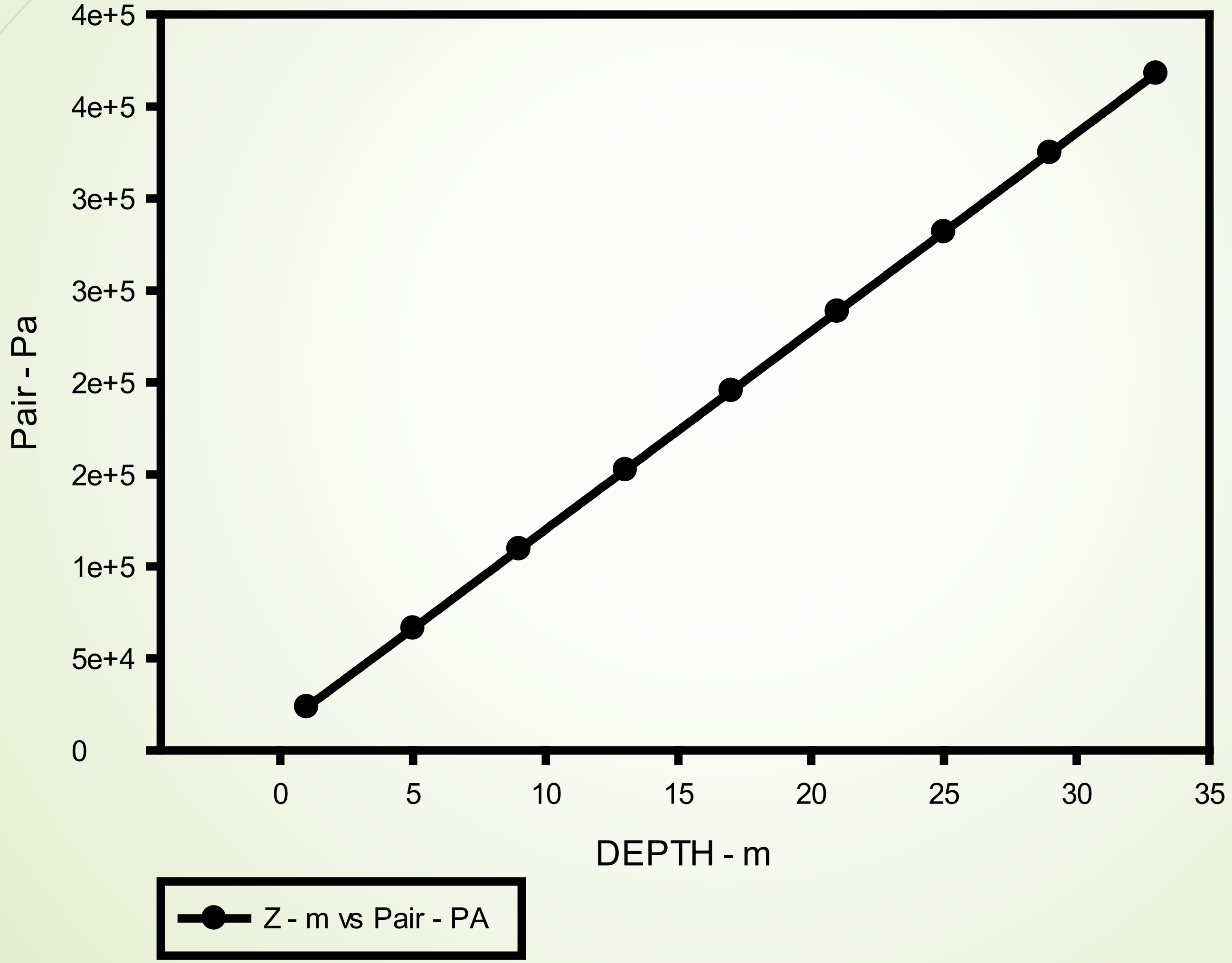
$$F_{air} = P_{air} \bullet A_{plate}$$

$$\sum_{\downarrow} F_z = 0$$

$$+F_r \cos\theta - F_{air} \cos\theta + mg - A_z = 0$$

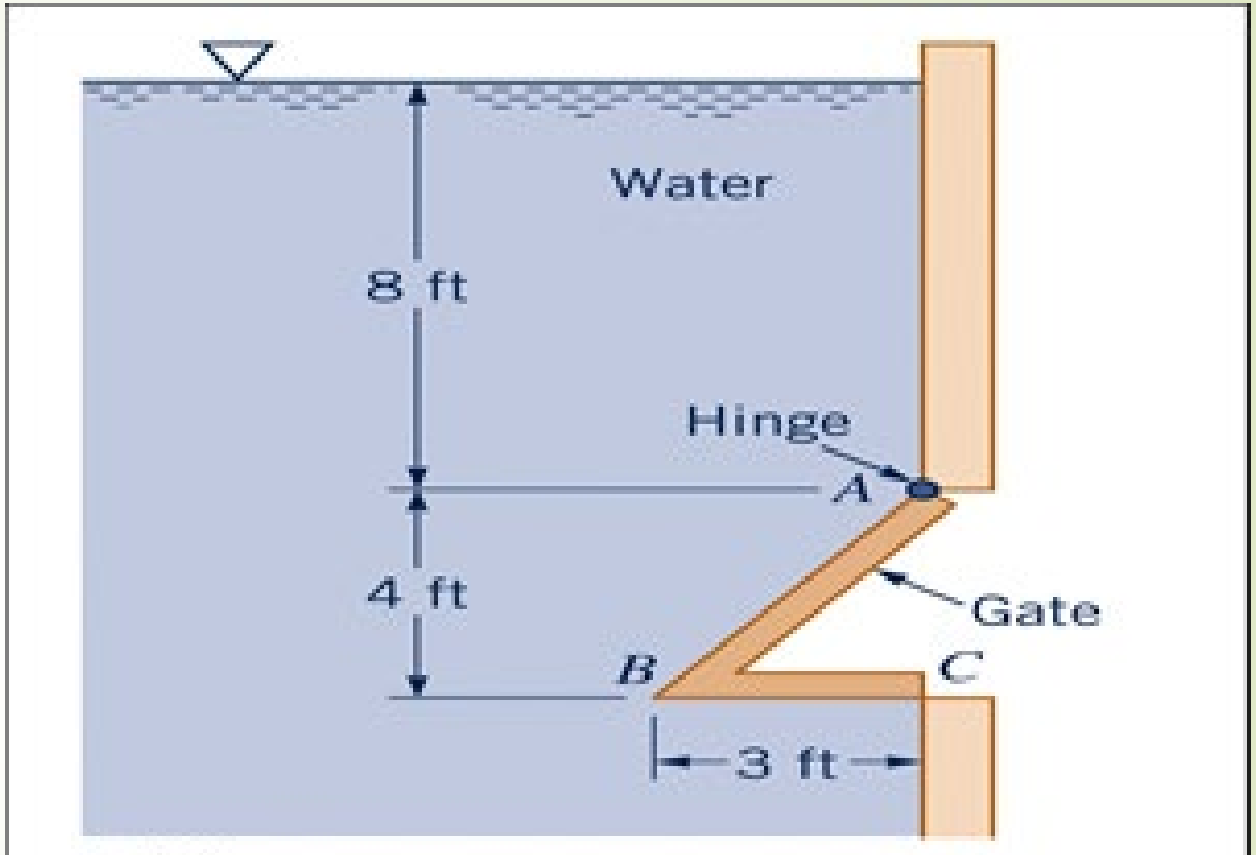
$$A_z = \cos\theta (F_r - F_{air}) + mg$$

Submerged Surface
Depth vs Pair
D=2m, Theta = 30



- A gate having a cross section as shown closes an opening 5ft wide and 4 ft high as shown and weighs 500 lbs. The Center of Gravity is 1ft to the left of AC and 2ft above BC. Horizontal Surface BC is constrained by horizontal force at vertical wall C.

- a. Draw FBD and show ALL required information.
- b. Determine the pressure force (lbf) on surface BC and line of action of force.
- c. Determine the pressure force (lbf) on surface AB and line of action.
- d. Determine the horizontal force C (lbf).
- e. Derive parametric equations that could be used to simulate/model the hinge forces at A and verify units.



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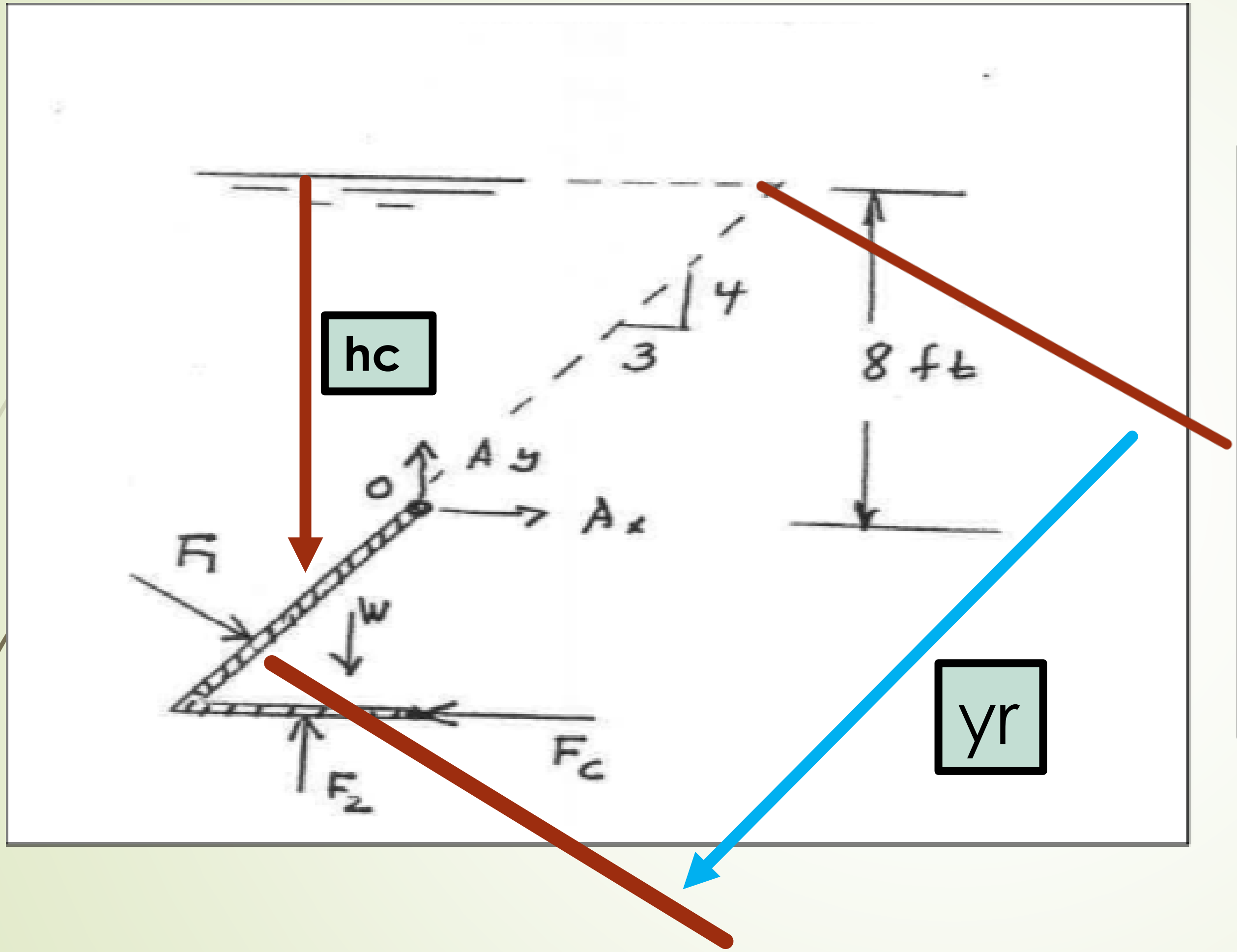

"yc" measured from SURFACE along AXIS of plate to the plate CENTROID.

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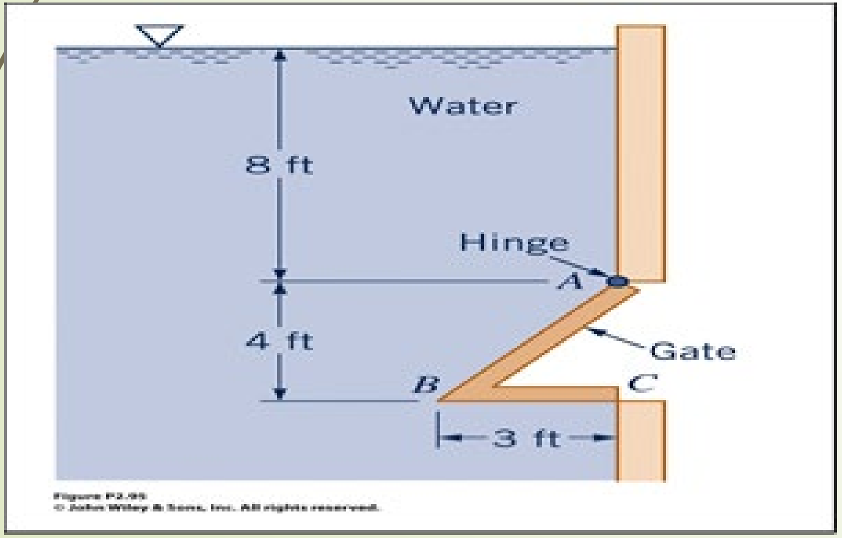
$$a)F_{BC} = F_2 = \gamma h_c A_p$$

(HORIZNTAL PLATE)

$$= \gamma \frac{lbf}{ft^3} \bullet 12\,ft \bullet (3\,ft x 5\,ft)$$

$$= 11,232 lbf$$

LOA = 1.5ft to right of B



$$b)F_{AB} = F_1 = \gamma h_c A_p$$

$$\theta = \tan^{-1}\frac{4}{3} = 53.1^0$$

$$\sin\theta = \frac{4}{l}, l = \frac{4}{\sin\theta} = 5\,ft$$

$$F_1 = \gamma \frac{lbf}{ft^3} \bullet (h_c = 10\,ft) \bullet (5\,ft x 5\,ft)$$

$$F_1 = 15,600 lbf$$

$$y_c = L_1 + \frac{l}{2} = \frac{8}{\sin\theta} + \frac{5}{2} = 12.5\,ft$$

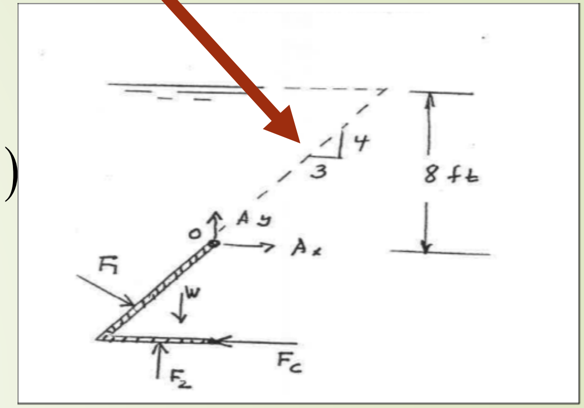
OR

$$\sin\theta = \frac{h_c}{y_c} \rightarrow y_c = \frac{h_c}{\sin\theta} = 12.5\,ft$$

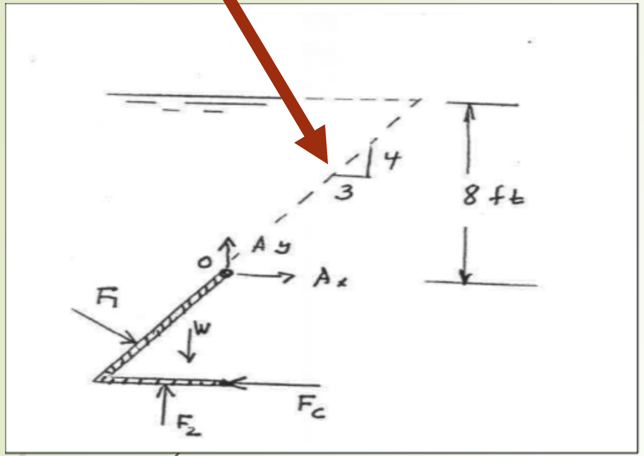
LOA

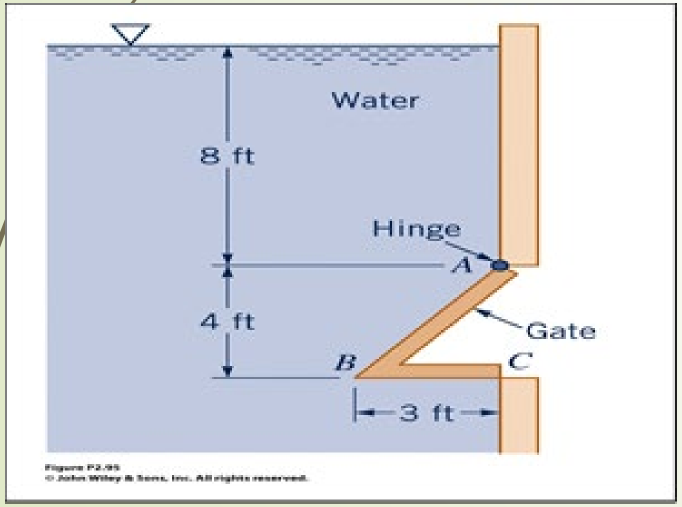
$$y_r = y_c + \frac{Ixc}{y_c A_p} = 12.5\,ft + \frac{\left(\frac{1}{12} 5 \bullet 5^3\right) ft^4}{12.5\,ft \bullet (5\,ft x 5\,ft)} = 12.67\,ft$$

L1



L1





$$d)\sum_{CCW+} M_A = 0$$

$$+F_1(y_r - L_1) - F_2(1.5\,ft) - F_c(4\,ft) + mg(1\,ft) = 0$$

$$F_c[lbf] = \frac{F_1(y_r - L_1)[lbf-ft] - F_2(1.5\,ft) + mg(1)[lbf-ft]}{4.0[ft]}$$

$$e)\sum_{\rightarrow} F_x = 0 \rightarrow \text{PARAMETRIC EXPRESSION}$$

$$+A_x - F_c + F_1\sin\theta = 0$$

$$A_x = F_c - F_1\sin\theta$$

$$\sum_{\uparrow} F_y = 0 \rightarrow \text{PARAMETRIC EXPRESSION}$$

$$+A_y - mg + F_2 - F_1\cos\theta = 0$$

$$A_y = mg - F_2 + F_1\cos\theta$$

NOTE INDICATION OF DIRECTION FOR FORCES/MOMENTS AS PLUS OR MINUS