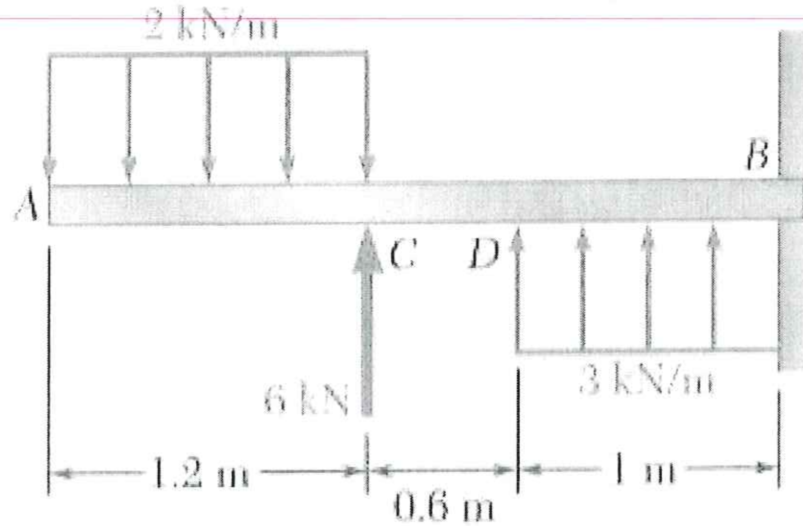
Wright State University
Department of Mechanical and Materials Engineering

ME 212 Statics, Spring 2005

FINAL EXAM
Open Book, Closed Notes, Do not write on this sheet, Show all work

1. (20 points) For the beam and loading shown, draw the shear and bending-moment diagrams, and determine the magnitude and location of the maximum shear and bending moment.



3 GOT THIS RIGHT.

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16
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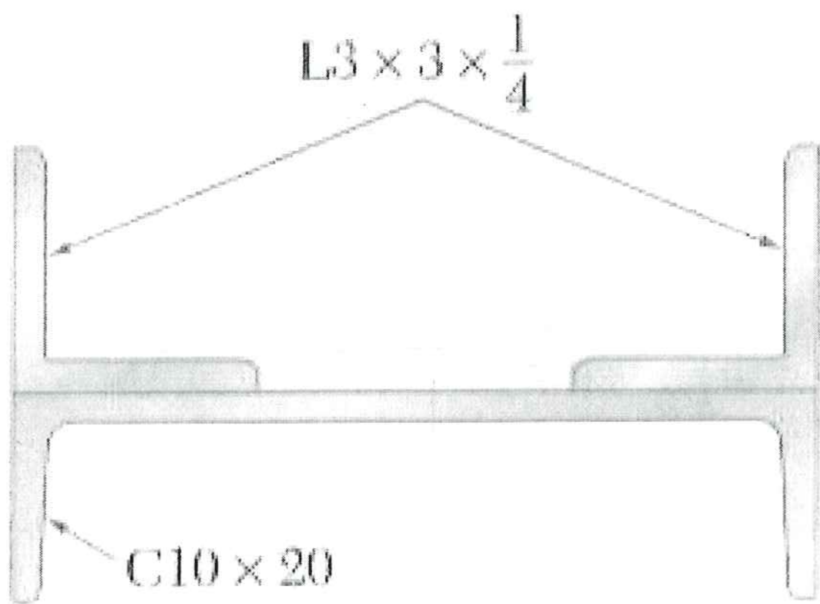
2. (15 points) Two L3 × 3 × ¼-in. angles are welded to a C10 × 20 channel. Determine the moments of inertia of the combined section with respect to the centroidal axes respectively parallel and perpendicular to the web of the channel.



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9

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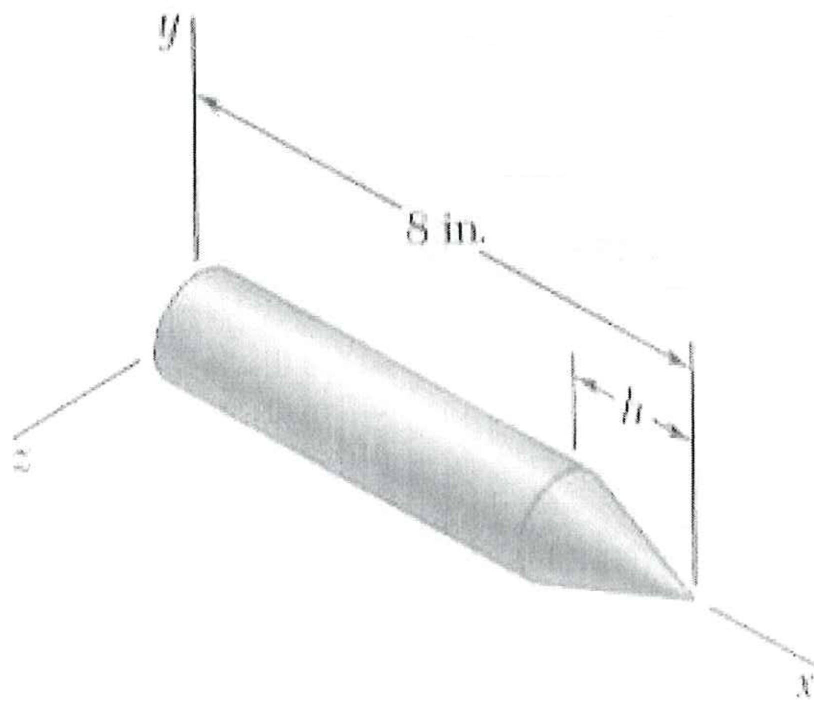
3. (20 points) A portion of an 8-in.-long steel rod of diameter 1.50 in. is turned to form the conical section shown. Knowing that the turning process reduces the moment of inertia of the rod with respect to the x axis by 20 percent, determine the height h of the cone. The specific weight of steel is 0.284 lb/in^3, and the volume of a cone is

$$V_{\text{cone}} = \frac{\pi}{3} r^2 h$$

where r is the radius of the base of the cone, and h is the height of the cone.



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I GOT PART 1 RIGHT 25

8 " " 2 " 22

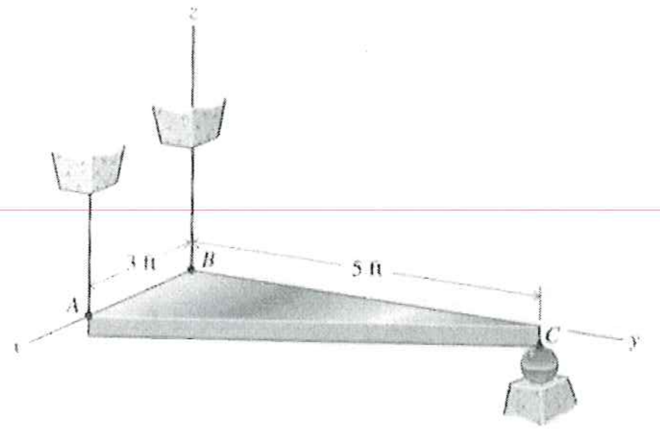
19

4. (45 points total) Part 1: (20 points) Draw the freebody diagrams for the following situations. 16
Part 2: (25 points) Solve problem (a).

13

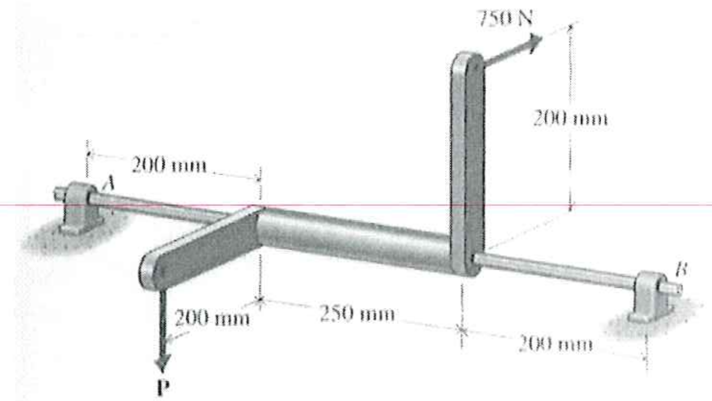
10

(a)



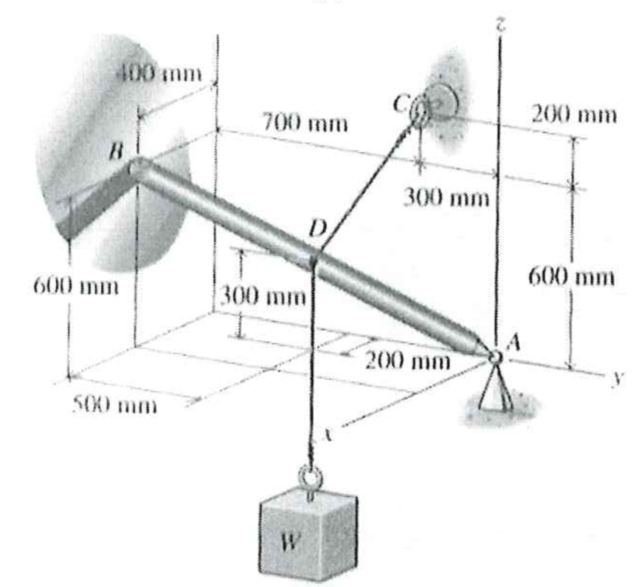
The triangular plate of uniform thickness shown weighs 750 lb. Determine the tensions in the two cables supporting the plate and the reaction at the ball support.

(b)



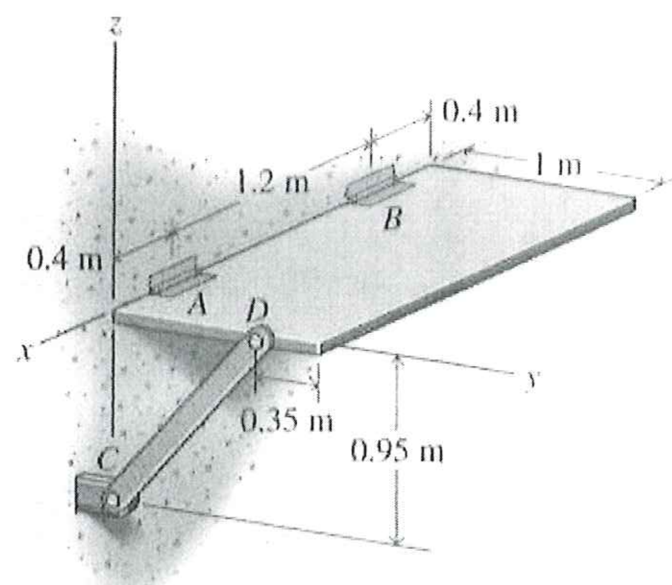
The shaft with two levers is used to change the direction of a force. Determine the force **P** required for equilibrium and the reactions at supports *A* and *B*. The support at *A* is a ball bearing and the support at *B* is a thrust bearing. The bearings exert only force reactions on the shaft.

(c)



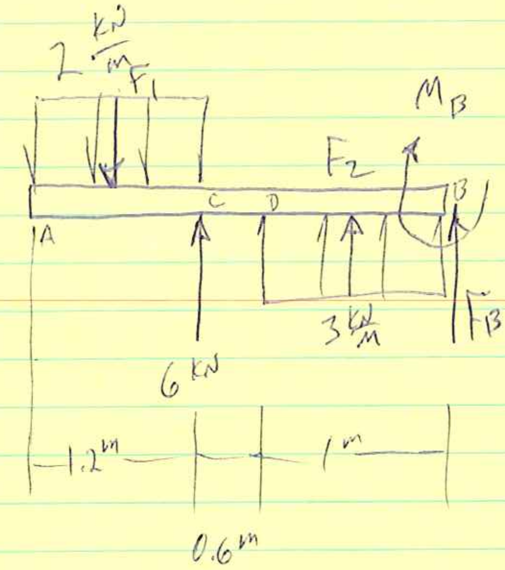
The block *W* has a mass of 250 kg. Bar *AB* rests against a smooth vertical wall at end *B* and is supported at end *A* with a ball-and-socket joint. The two cables are attached to a point on the bar midway between the ends. Determine the reactions at supports *A* and *B* and the tension in cable *CD*.

(d)



The door shown has a mass of 25 kg and is supported in a horizontal position by two hinges and a bar. The hinges have been properly aligned; therefore, they exert only force reactions on the door. Assume that the hinge at *B* resists any force along the axis of the hinge pins. Determine the reactions at supports *A*, *B*, and *D*.

PROB. 1



FIND REACTION FORCES:

$$F_1 = \left(2\tfrac{kN}{m}\right)\left(1.2^m\right) = 2.4^{kN}$$

$$F_2 = \left(3\tfrac{kN}{m}\right)\left(1^m\right) = 3^{kN}$$

$\Sigma F_y = 0$:

$$-2.4 + 6 + 3 + F_B = 0$$

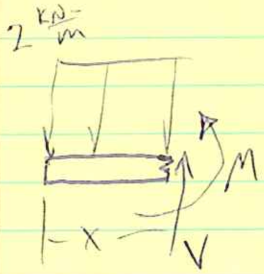
$$F_B = -6.6^{kN}$$

$\Sigma M_B = 0$ $\overset{B}{\circlearrowleft}$:

$$(0.6 + 0.6 + 1^m)(2.4^{kN}) - (1.6)(6) - (0.5)(3) - M_B = 0$$

$$M_B = -5.82^{kN\text{-}m}$$

FBD: A - C



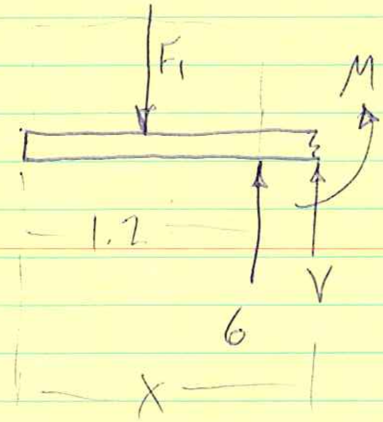
$\Sigma F_y = 0$: $V - 2X = 0$, $\boxed{V = 2X}$

$\Sigma M = 0$: $M + \left(\frac{X}{2}\right)(2X) = 0$

$$\boxed{M = -X^2}$$

PROB. 1 CONT.

FBD: C − D



$\Sigma F_y = 0: V + 6 - 2.4 = 0$

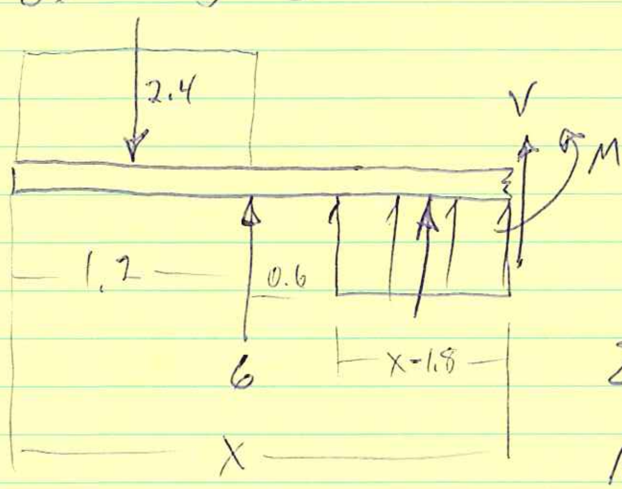
$\boxed{V = -3.6^{kN}}$

$\Sigma M = 0: \; M - (x-1.2)(6) + (x-0.6)(2.4) = 0$

$M = 6x - 7.2 - 2.4x + 1.44$

$\boxed{M = 3.6x - 5.76}$

FBD: D − B



$\Sigma F_y = 0:$

$V - 2.4 + 6 + (3\tfrac{kN}{m})(x-1.8) = 0$

$\boxed{V = -3x + 1.8}$

$\Sigma M = 0:$

$M + (x-0.6)(2.4) - (x-1.2)(6)$

$-\tfrac{1}{2}(x-1.8)(x-1.8)(3) = 0$

$M + 2.4x - 1.44 - 6x + 7.2 - \tfrac{3}{2}(x^2 - 3.6x + 3.24) = 0$

$M - 1.5x^2 + 1.8x + 0.9 = 0$

$\boxed{M = 1.5x^2 - 1.8x - 0.9}$

PROB. 1 CONT.

@ $X = 0$, $V = 0$, $M = 0$

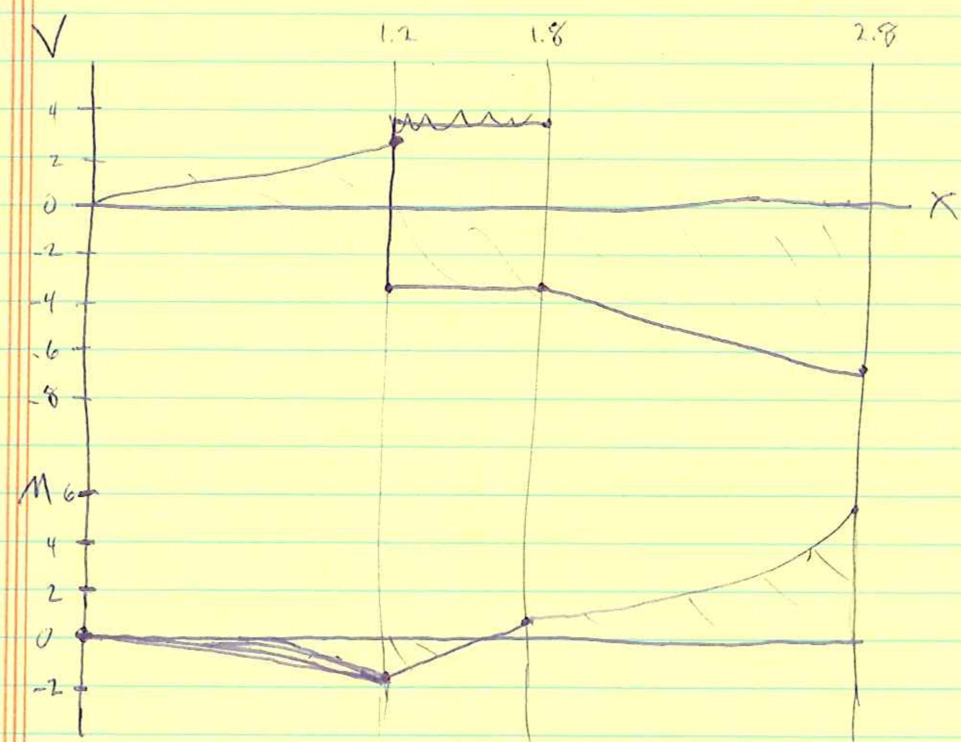
$X = 1.2^-$: $V = 2.4$, $M = -1.44$

$X = 1.2^+$: $V = -3.6$, $M = -1.44$

$X = 1.8^-$: $V = -3.6$, $M = 0.72$

$X = 1.8^+$: $V = -3.6$, $M = 0.72$

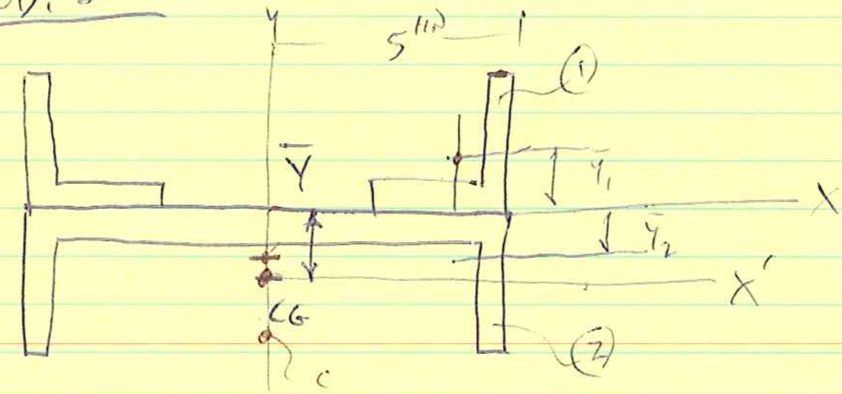
$X = 2.8^-$: $V = -6.6$, $M = 5.82$



$V_{max} = 6.6^{kN}$, $M_{max} = 5.82^{kN-m}$

BOTH AT $X = 2.8^m$ (AT THE WALL)

PROB. 2



FIND $\bar{Y}$:

$$\bar{Y} = \frac{\Sigma \bar{y}_i A_i}{\Sigma A_i} = \frac{2 y_1 A_1 + y_2 A_2}{2 A_1 + A_2}$$

$$\bar{Y} = \frac{2(0.842)(1.44) + (-0.606)(5.88)}{2(1.44) + (5.88)}$$

$$\boxed{\bar{Y} = \cancel{+0.154^{in}}} = -0.130^{in}$$

$$\bar{I}_x = 2(I_x)_L + (I_x)_c$$

$$(I_x)_L = (\bar{I}_x)_L + Ad^2$$
$$= (1.24^{in^4}) + (1.44^{in^2})(0.13 + 0.842)^2$$

$$(I_x)_L = 2.60^{in^4}$$

$$(I_x)_c = (\bar{I}_x)_c + Ad^2$$
$$= (2.81) + (5.88)(0.606 - 0.13)^2$$

$$(I_x)_c = 4.14^{in^4}$$

$$\boxed{\bar{I}_x = 2(2.60) + (4.14) = 9.34^{in^4}}$$

PROB. 2 CONT.

$$\bar{I}_y = 2(I_y)_L + (\bar{I}_y)_c$$

$$(I_y)_L = (\bar{I}_y)_L + Ad^2$$

$$= (1.24) + (1.44)(5 - 0.842)^2$$

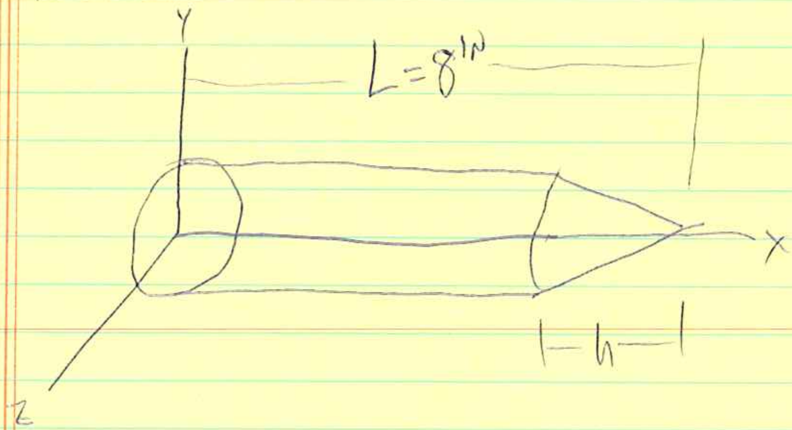
$$(I_y)_L = 26.1 \text{ IN}^4$$

$$(\bar{I}_y)_c = 78.9 \text{ IN}^4$$

$$(\bar{I}_y) = 2(26.1 \text{ IN}^4) + (78.9 \text{ IN}^4)$$

$$\boxed{(\bar{I}_y) = 131 \text{ IN}^4}$$

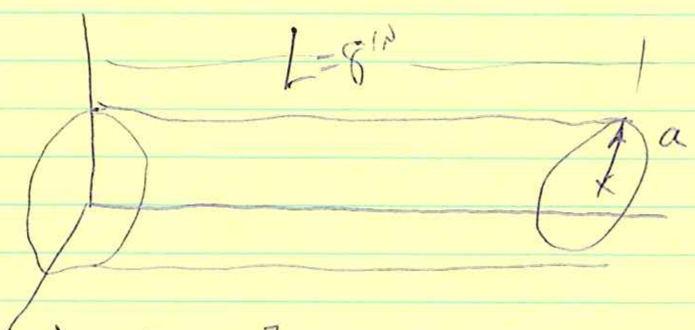
PROB. 3



$D = 1.5^{IN}$

$(I_x)_{CON.} = 0.8\,(I_x)_{ROD}$ FIND h

FOR A ROD,



$D = 1.5^{IN}$

$(I_x)_R = \frac{1}{2} M a^2$.

$M = \rho V = \rho \cdot \pi a^2 L$

$$\boxed{(I_x)_R = \frac{\pi}{2} \rho a^4 L}$$

FOR ROD/CONE,

$(I_x)_{CON} = (I_x)_R + (I_x)_C$

$= \frac{1}{2} M_R a^2 + \frac{3}{10} M_C a^2$

PROB. 3 CONT.

$M_R = \rho V_R = \rho \pi a^2 (L-h)$

$M_c = \rho V_c = \rho \cdot \frac{\pi}{3} a^2 h$

$-\frac{5}{10} + \frac{1}{10} = -\frac{4}{10}$
$= -\frac{2}{5}$

$$(I_x)_{CON} = \frac{1}{2} \cdot \rho \pi a^4 (L-h) + \frac{3}{10} \cdot \rho \frac{\pi}{3} a^4 h$$
$$= \frac{\pi}{2} \rho a^4 L - \frac{\pi}{2} \rho a^4 h + \frac{\pi}{10} \rho a^4 h$$
$$= \pi \rho a^4 \left(\frac{1}{2} L - \frac{2}{5} h\right)$$
$$= \pi \rho a^4 \left(\frac{5}{10} L - \frac{4}{10} h\right)$$

$$(I_x)_{CON} = \frac{\pi}{10} \rho a^4 (5L - 4h)$$

$$(I_x)_{CON} = 0.8 (I_x)_{ROD}$$

$$\cancel{\frac{\pi}{10}} \cancel{\rho a^4} (5L - 4h) = \frac{4}{5} \cdot \cancel{\frac{\pi}{2}} \cancel{\rho a^4} L$$

$$5L - 4h = 4L$$

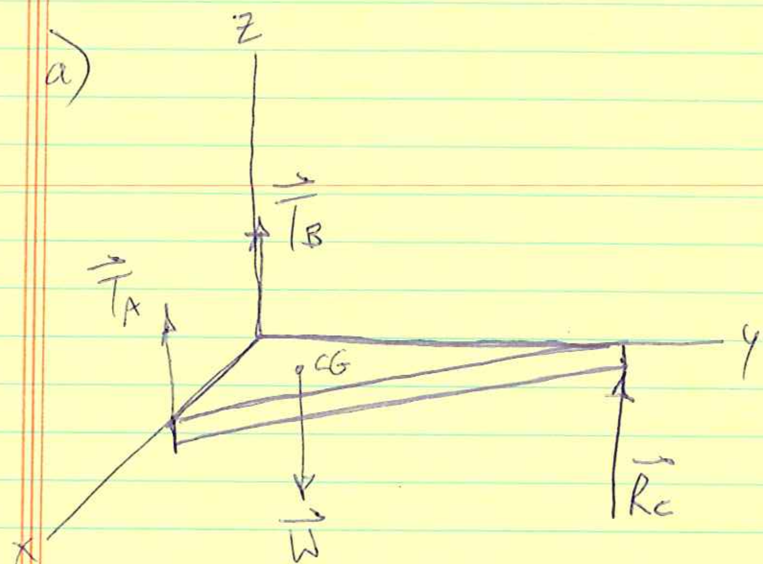
$$4h = L$$

$$\boxed{h = \frac{L}{4}} = 2^{IN}$$

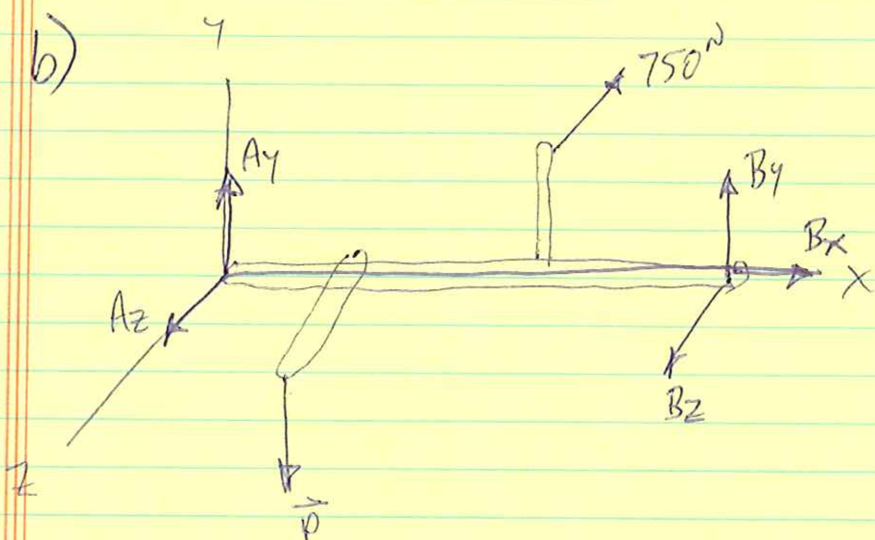
PROB. 4

PART 1:

a)

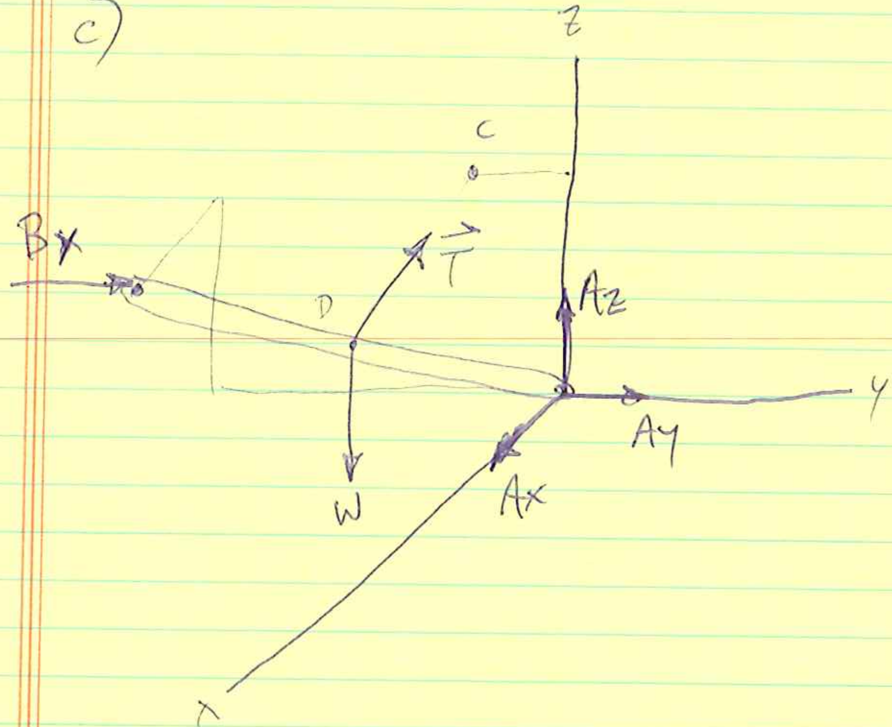


b)

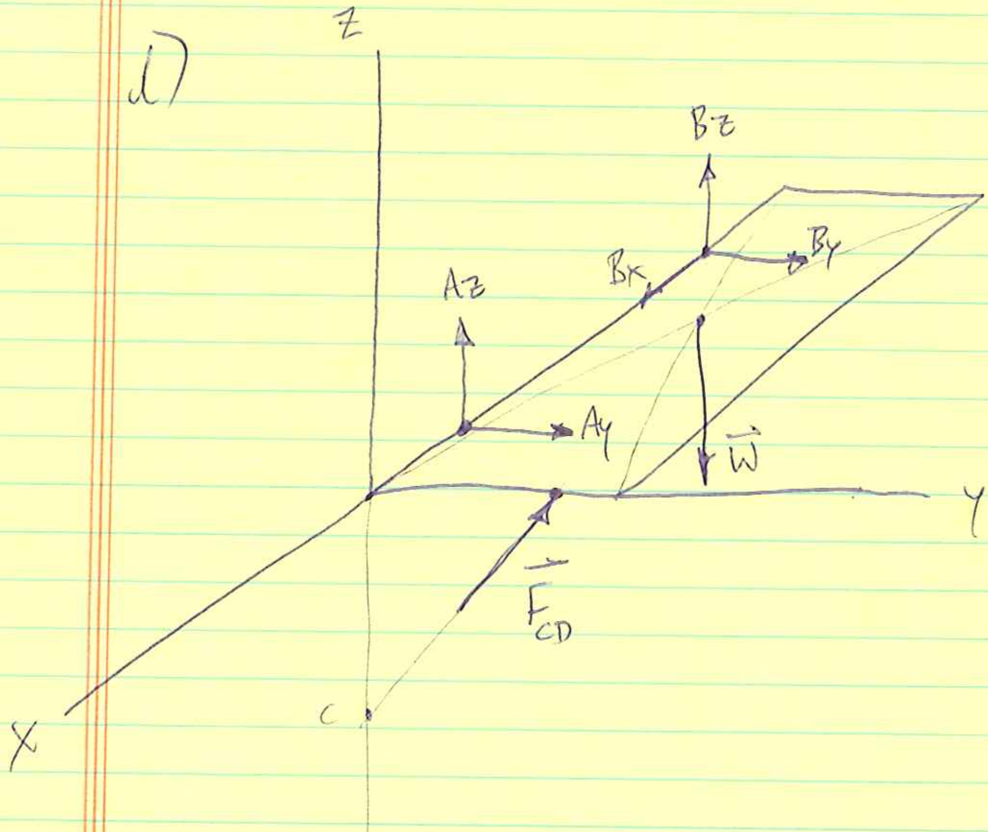


PROB. 4 CONT.

c)



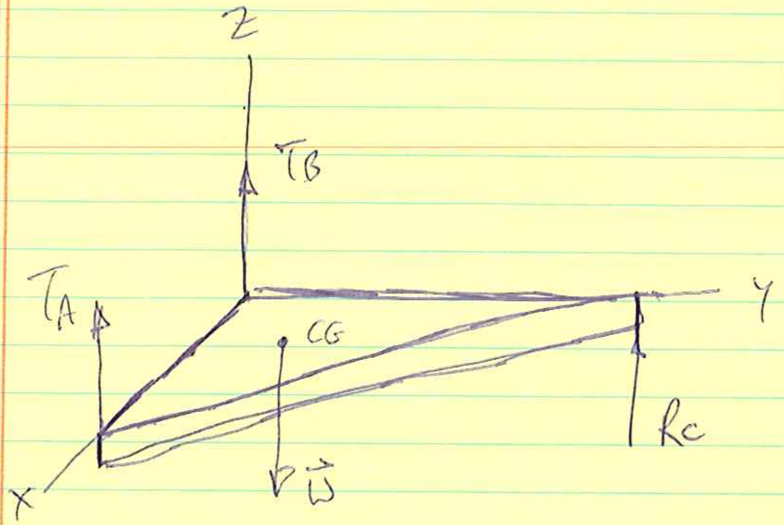
d)



PROB. 4 CONT.

PART 2:

SOLVE PART a)



$W = 750^{LB}$

FIND T_A, T_B, R_C

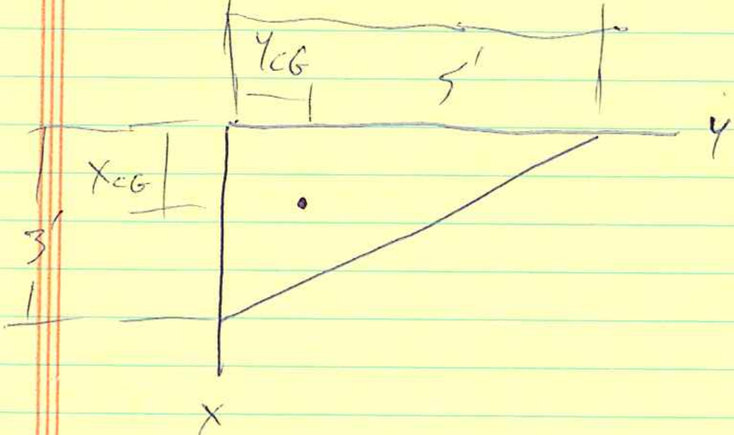
$\vec{T_A} = (T_A)\,\hat{k}$

$\vec{T_B} = (T_B)\,\hat{k}$

$R_C = (R_C)\,\hat{k}$

$\vec{W} = (-750)\,\hat{k}$

FIND POSITION OF CG:



$X_{CG} = \frac{1}{3}(3^{ft}) = 1^{ft}$

$Y_{CG} = \frac{1}{3}(5^{ft}) = 1.67^{ft}$

$\Sigma F_Z = 0$:

$T_A + T_B + R_C - 750 = 0$

$\Sigma \vec{M_O} = 0$:

$\vec{M_1} + \vec{M_2} + \vec{M_3} = 0$

PROB. 4 CONT.

FIND POSITION VECTORS:

$\vec{r}_A = (3)\hat{i}$ ft

$\vec{r}_C = (5)\hat{j}$ ft

$\vec{r}_{CG} = (1)\hat{i} + (1.67)\hat{j}$ ft

$$\vec{M}_1 = \vec{r}_A \times \vec{T}_A = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 0 & 0 \\ 0 & 0 & T_A \end{vmatrix}$$

$\vec{M}_1 = (-3T_A)\hat{j}$ FT-LB

$$\vec{M}_2 = \vec{r}_C \times \vec{R}_C = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 5 & 0 \\ 0 & 0 & R_C \end{vmatrix}$$

$\vec{M}_2 = (5R_C)\hat{i}$ FT-LB

$$\vec{M}_3 = \vec{r}_{CG} \times \vec{W} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1.67 & 0 \\ 0 & 0 & -750 \end{vmatrix}$$

$\vec{M}_3 = [(1.67)(-750)]\hat{i} - [-750]\hat{j}$ FT-LBF

$\vec{M}_3 = (-1250)\hat{i} + (750)\hat{j}$

PROB. 4 CONT.

$\Sigma \vec{M}_0 = 0$:

$(-3T_A)\hat{j} + (5R_c)\hat{i} + (-1250)\hat{i} + (750)\hat{j} = 0$

$\hat{i}: \quad 5R_c - 1250 = 0, \quad R_c = 250^{LB}$

$\hat{j}: \quad -3T_A + 750 = 0, \quad T_A = 250^{LB}$

$T_A + T_B + R_c = 750$

$T_B = 750 - 250 - 250$

$T_B = 250^{LB}$