Wright State University
Department of Mechanical and Materials Engineering

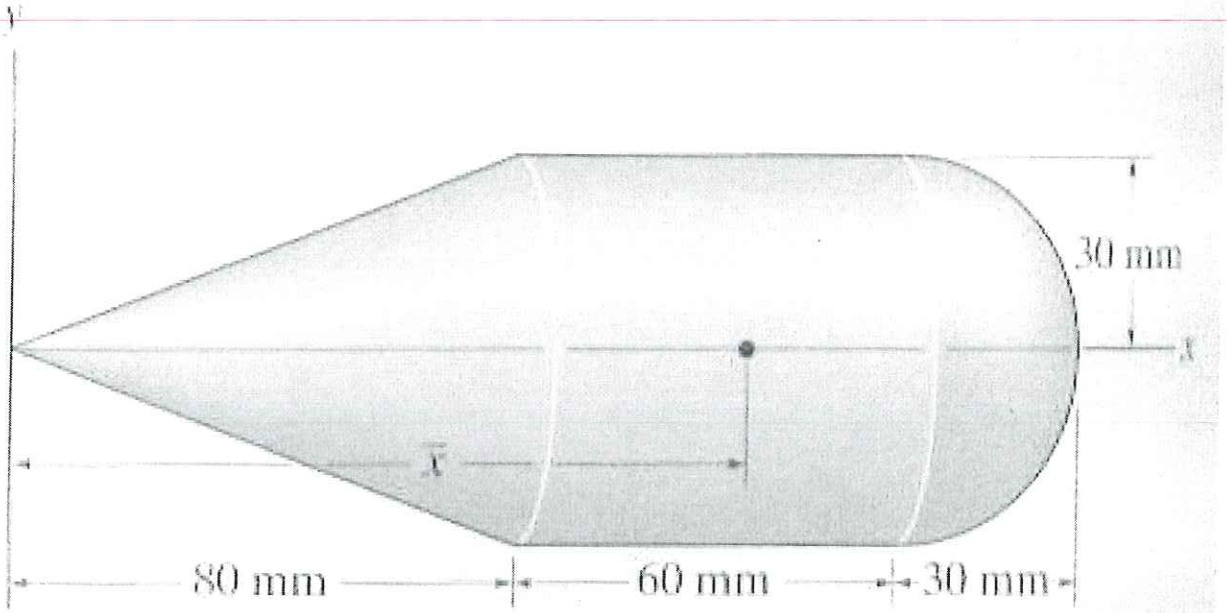
ME 212 Statics, Fall 2006

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

1. (25 points) Determine the location $\bar{x}$ of the center of gravity of the solid made from a hemisphere, cylinder, and cone.

IS GOT THIS RIGHT

25
22
19
16
13
10
~~7~~



RAW SCORES

100	68	49
92	67	47
88	67	42
83	64	40
83	62	32
80	61	29
79	59	22
78	58	
3x77	57	
76	56	
75	55	
72	55	
70	3x53	

$\bar{X} = 63.7$

ADJUSTED SCORES

117	75	37
108	73	34
103	71	26
97.1	69	
97.1	68	
94	67	
92	~~66~~	
91	66	
3x90	64	
89	64	
88	3x62	
84	57	
82	55	
80	49	
78	47	
78		

$\bar{X} = 74.5$

A.S. = R.S. x 1.17

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I GOT THIS RIGHT.

2. (25 points) Determine the moment of inertia for the beam's cross-sectional area with respect to the x' centroidal axis. Neglect the size of all the rivet heads, R, for the calculation. Handbook values for the area, moment of inertia, and location of the centroid C of one of the angles are listed in the figure.

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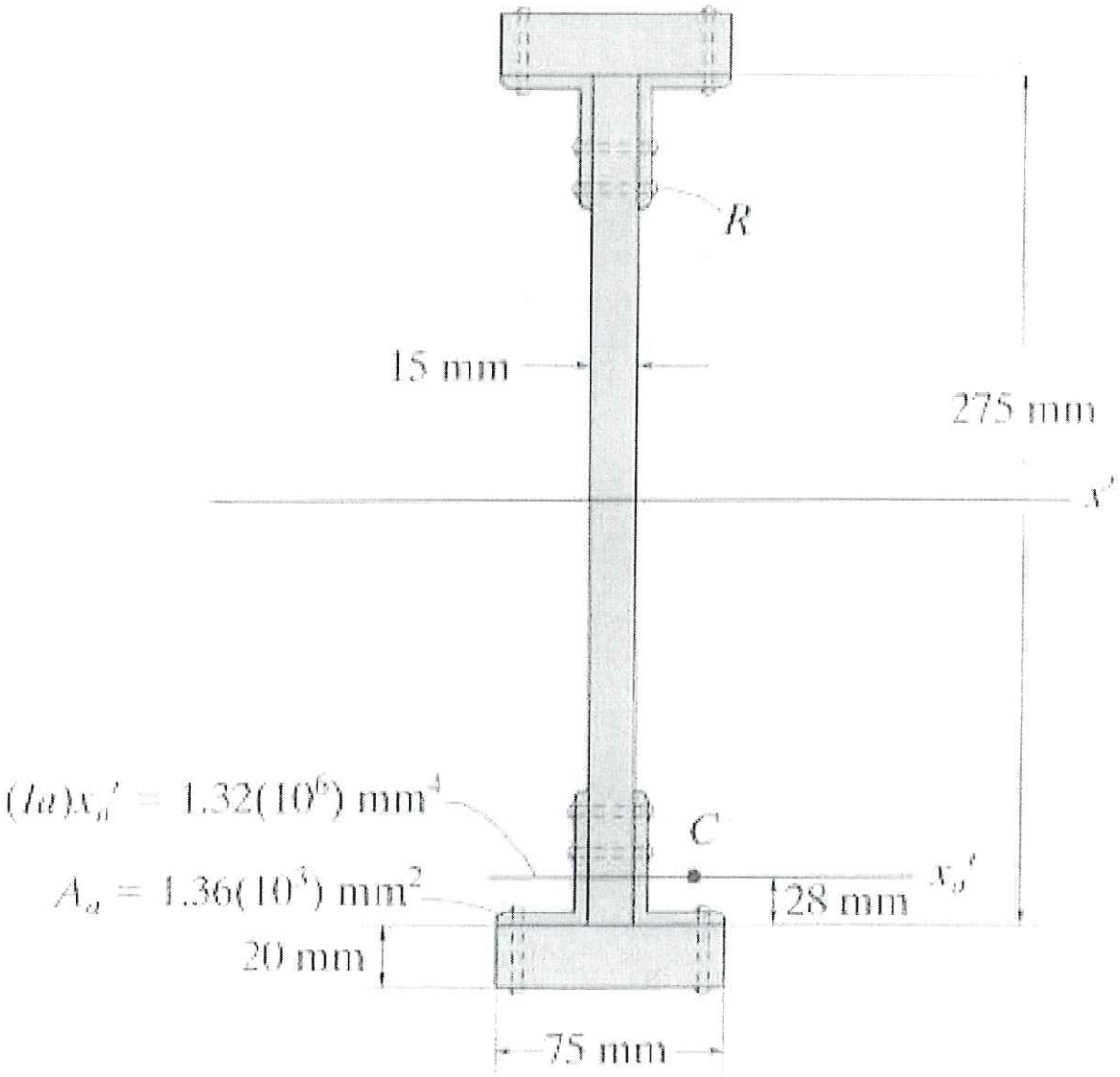

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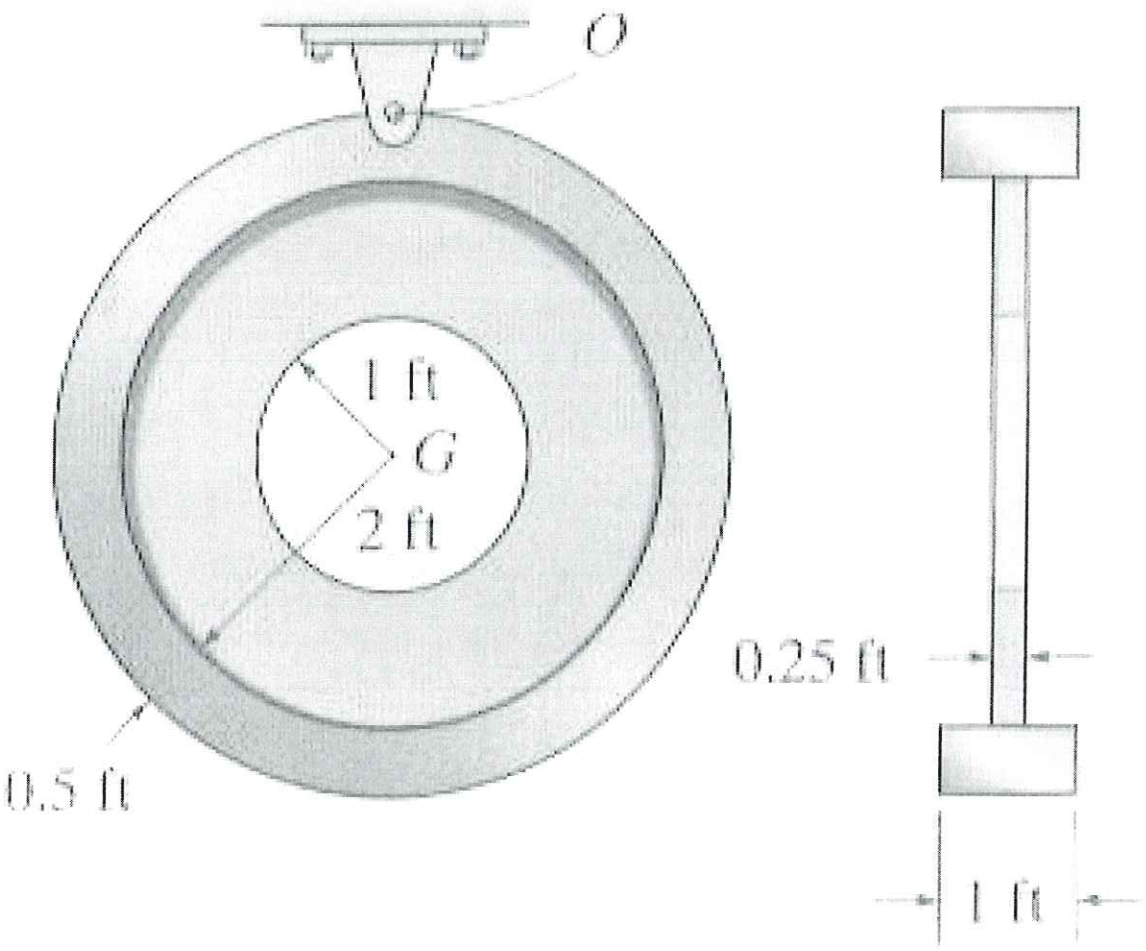
4 GOT THIS RIGHT

3. (30 points) Determine the mass moment of inertia of the assembly about an axis which is perpendicular to the page and passes through point O. The material has a specific weight of $\gamma = 90\ \text{lb/ft}^3$.

30
27
24
21
18
15
12



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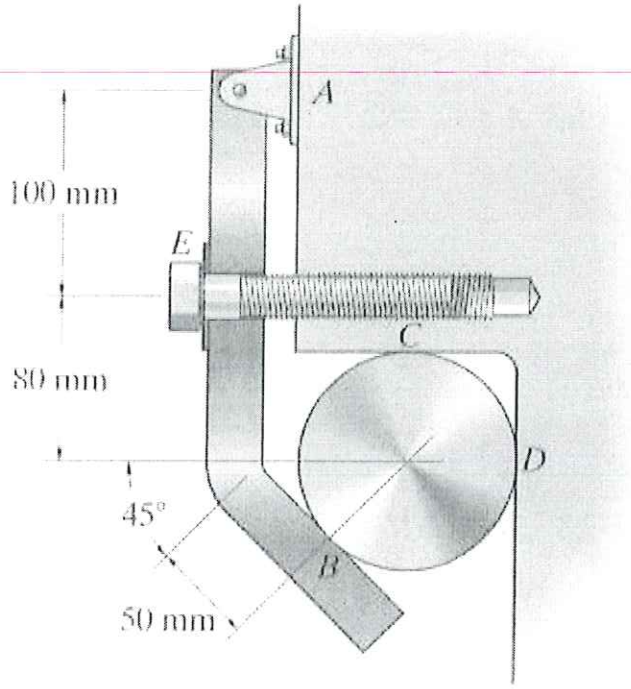
I GOT THIS RIGHT

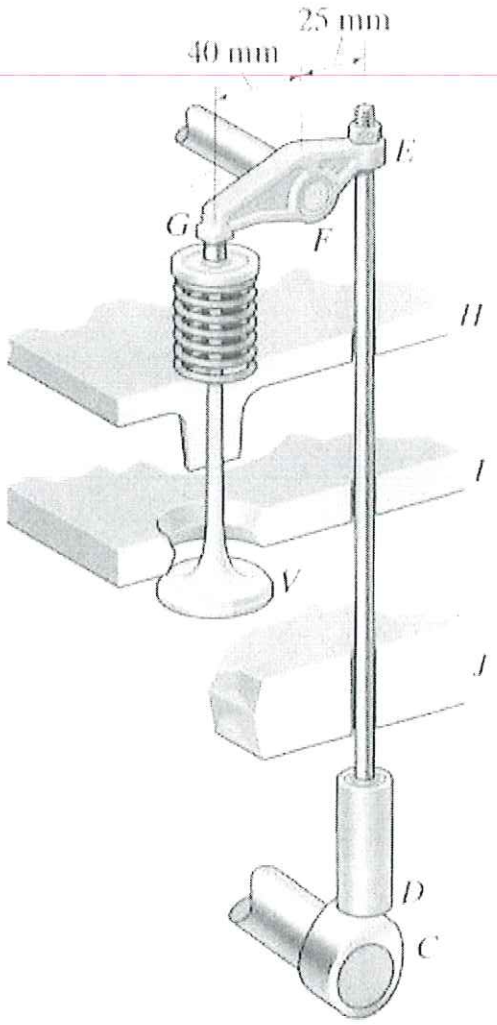
4. (20 points) Draw the free-body diagrams for the four following situations.

(a)



The link is used to hold the rod in place. Determine the required axial force on the screw at *E* if the largest force to be exerted on the rod at *B*, *C*, or *D* is to be 100 N. Also, find the magnitude of the reaction force at pin *A*. Assume all surfaces of contact are smooth.

(b)



Operation of exhaust and intake valves in an automobile engine consists of the cam *C*, push rod *DE*, rocker arm *EFG* which rides on a smooth bearing at *F*, and a spring and valve, *V*. If the compression in the spring is 20 mm when the valve is open as shown, determine the normal force acting on the cam lobe at *C*. Assume the contact between the cam and the push rod at *D* is normal and smooth. The spring has a stiffness of 300 N/m.

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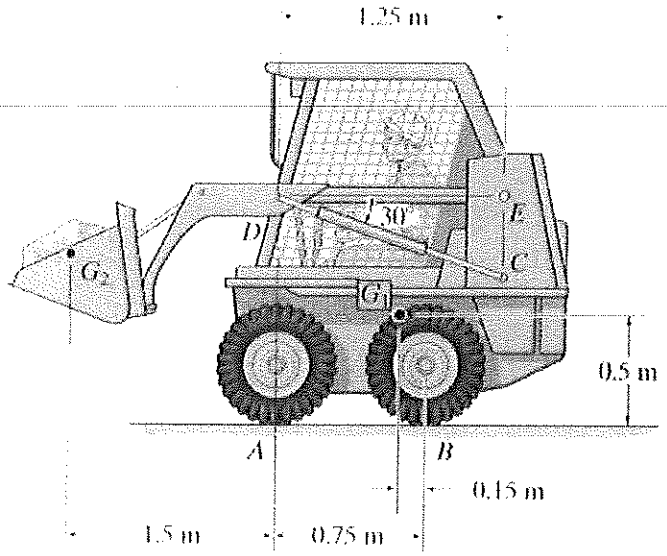
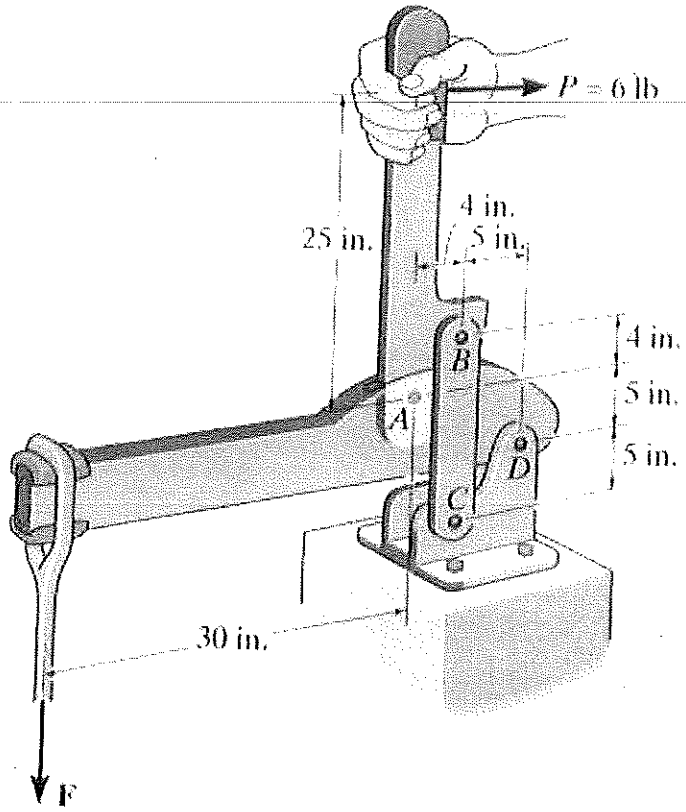
(c)



The skid steer loader has a mass of 1180 kg, and in the position shown the center of mass is at G_1. If there is a 300-kg stone in the bucket, with center of mass at G_2, determine the reactions of each pair of wheels A and B on the ground and the force in the hydraulic cylinder CD and at the pin E. There is a similar linkage on each side of the loader.

(d)



If a force of $P = 6$ lb is applied perpendicular to the handle of the mechanism, determine the magnitude of force F for equilibrium. The members are pin-connected at A, B, C, and D.

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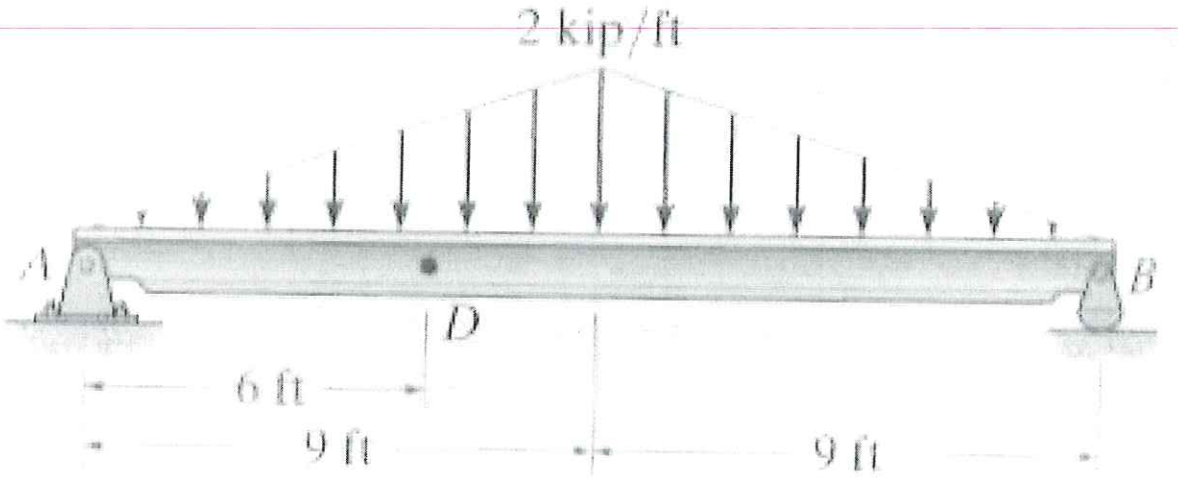
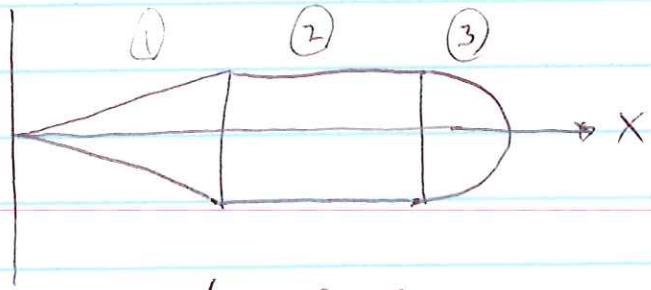
3 GOT THIS RIGHT

5. Bonus Question: (20 points, **No partial credit will be awarded**) Determine the internal shear force and moment acting at point *D* of the beam.



9-76



VOLUME 1: CONE

$$\bar{X} = \frac{h}{4} = \frac{(80^{mm})}{4} = 20^{mm}$$

$$\bar{X}_1 = 80 - 20 = 60^{mm}$$

$$V_1 = \frac{1}{3}\pi a^2 h = \frac{1}{3}\pi (30^{mm})^2 (80^{mm}) = 7.540 \times 10^{4}\ mm^3$$

VOLUME 2: CYLINDER

$$\bar{X} = \frac{h}{2} = \frac{(60^{mm})}{2} = 30^{mm}$$

$$\bar{X}_2 = 80 + 30 = 110^{mm}$$

$$V_2 = \pi a^2 h = \pi (30^{mm})^2 (60^{mm}) = 1.696 \times 10^{5}\ mm^3$$

VOLUME 3: HEMISPHERE

$$\bar{X} = \frac{3a}{8} = \frac{3}{8}(30^{mm}) = 11.25^{mm}$$

$$\bar{X}_3 = 80 + 60 + 11.25 = 151.3^{mm}$$

$$V_3 = \frac{2}{3}\pi R^3 = \frac{2}{3}\pi (30^{mm})^3 = 5.655 \times 10^4 \ mm^3$$

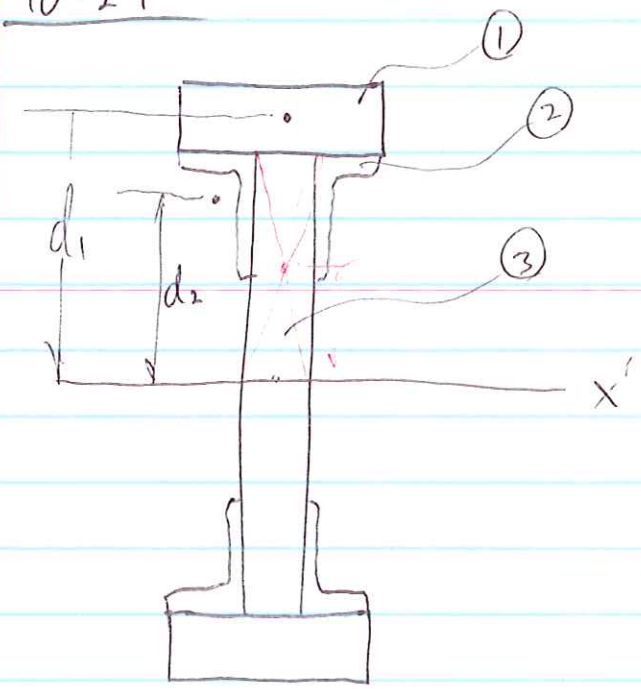
$$\bar{X} = \frac{\sum \bar{X}_i V_i}{\sum V_i}$$

CONE CYLINDER HEMISPHERE

$$\bar{X} = \frac{(60^{mm})(7.54 \times 10^4 \ mm^3) + (110)(1.696 \times 10^5) + (151.3)(5.655 \times 10^4)}{(7.54 \times 10^4) + (1.696 \times 10^5) + (5.655 \times 10^4)}$$

$$\boxed{\bar{X} = 105.2^{mm}}$$

10-29



$$(I_x)_1 = \bar{I}_x + A_1 d_1^2$$

$$(\bar{I}_x)_1 = \frac{1}{12} b h^3 = \frac{1}{12}(75^{mm})(20^{mm})^3 = 5.0 \times 10^4 \ mm^4$$

$$A_1 = bh = (75^{mm})(20^{mm}) = 1500^{mm^2}$$

$$d_1 = \frac{1}{2}(275^{mm}) + \frac{1}{2}(20^{mm}) = 147.5^{mm}$$

$$(I_x)_1 = (5.0 \times 10^4 \ mm^4) + (1500^{mm^2})(147.5^{mm})^2$$

$$(I_x)_1 = 3.268 \times 10^7 \ mm^4$$

$$(I_x)_2 = \bar{I}_x + A_2 d_2^2$$

$$(\bar{I}_x)_2 = 1.32 \times 10^6 \ mm^4$$

$$A_2 = 1.36 \times 10^{3}\ mm^2$$

$$d_2 = \frac{1}{2}(275^{mm}) - (28^{mm}) = 109.5^{mm}$$

$$(I_x)_2 = (1.32 \times 10^{6\ mm^4}) + (1.36 \times 10^{3}\ mm^2)(109.5^{mm})^2$$

$$(I_x)_2 = 1.763 \times 10^{7}\ mm^4$$

$$(I_x)_3 = \frac{1}{12}bh^3 = \frac{1}{12}(15^{mm})(275^{mm})^3$$

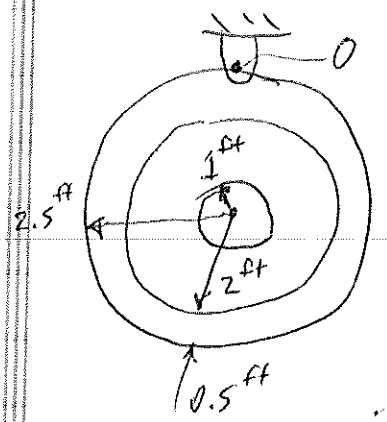
$$(I_x)_3 = 2.600 \times 10^{7}\ mm^4$$

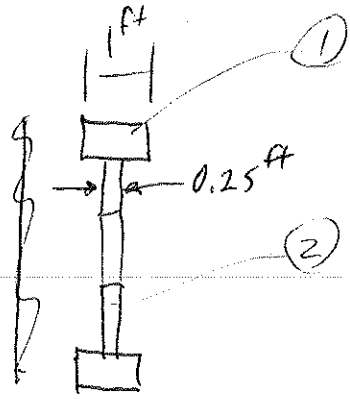
$$I_x = 2(I_x)_1 + 4(I_x)_2 + (I_x)_3$$

$$I_x = 2(3.268 \times 10^{7}) + 4(1.763 \times 10^{7}) + (2.6 \times 10^{7})$$

$$\boxed{I_x = 1.619 \times 10^{8}\ mm^4}$$

10-103





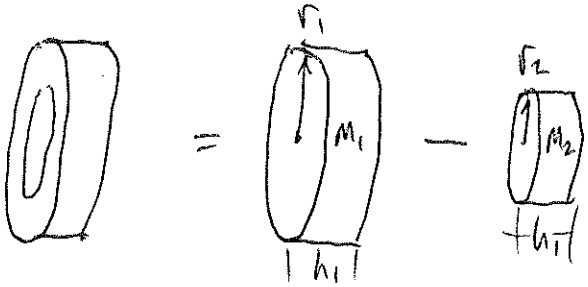
$\gamma = \left(90 \frac{LBF}{ft^3}\right)$

$\rho = (90$

$1\ LBF = 1 \frac{SLUG \cdot ft}{s^2}$

$\rho = \left(90 \frac{LBF}{ft^3}\right)\left(\frac{SLUG \cdot ft}{LBF \cdot s^2}\right)$

$I_o = \bar{I} + md^2$



$I_1 = \frac{1}{2} M_1 r_1^2 - \frac{1}{2} M_2 r_2^2$

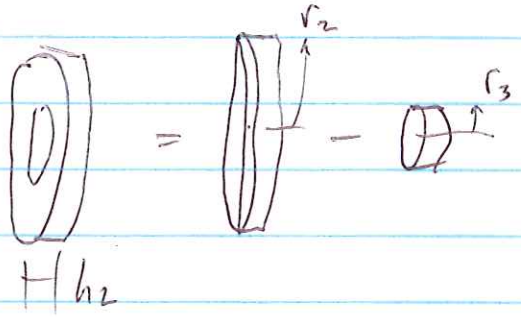
$m_1 = \rho V_1 = \rho \pi r_1^2 h_1$

$\rho = \frac{\gamma}{g} = \frac{\left(90 \frac{LBF}{ft^3}\right)}{\left(32.2 \frac{ft}{s^2}\right)} \cdot \left(\frac{SLUG \cdot ft}{LBF \cdot s^2}\right) = 2.795 \frac{SLUG}{ft^3}$

$I_1 = \frac{1}{2}\left[\rho \pi r_1^2 h_1 \cdot r_1^2 - \rho \pi r_2^2 h_1 \cdot r_2^2\right]$

$I_1 = \frac{1}{2} \rho \pi h_1 \left(r_1^4 - r_2^4\right)$

$I_1 = \frac{1}{2}\left(2.795 \frac{SLUG}{ft^3}\right) \pi \left(1\ ft\right)\left[\left(2.5\ ft\right)^4 - \left(2\ ft\right)^4\right] = 101.3\ SLUG \cdot ft^2$



$$I_2 = \frac{1}{2} M_2 r_2^2 - \frac{1}{2} M_3 r_3^2$$

$$M_2 = \rho V_2 = \rho \pi r_2^2 h_2$$

$$M_3 = \rho \pi r_3^2 h_2$$

$$I_2 = \frac{1}{2} \rho \pi h_2 \left(r_2^4 - r_3^4 \right)$$

$$I_2 = \frac{1}{2} \left(2.795 \frac{\text{SLUG}}{\text{ft}^3}\right) \pi (0.25\,\text{ft}) \left[(2\,\text{ft})^4 - (1\,\text{ft})^4 \right] = 16.46\ \text{SLUG}\cdot\text{ft}^2$$

$$\bar{I} = I_1 + I_2 = (101.3 + 16.46) = 117.8\ \text{SLUG}\cdot\text{ft}^2$$

3793

$$M = M_1 + M_2$$

$$M = \rho \pi h_1 (r_1^2 - r_2^2) + \rho \pi h_2 (r_2^2 - r_3^2)$$

$$M = \rho \pi \left[h_1 (r_1^2 - r_2^2) + h_2 (r_2^2 - r_3^2) \right]$$

$$M = \left(2.795 \frac{\text{SLUG}}{\text{ft}^3}\right) \pi \left\{ (1\,\text{ft}) \left[(2.5\,\text{ft})^2 - (2\,\text{ft})^2 \right] + (0.25\,\text{ft}) \left[(2\,\text{ft})^2 - (1\,\text{ft})^2 \right] \right\}$$

$m = 26.34\ \text{SLUG}$

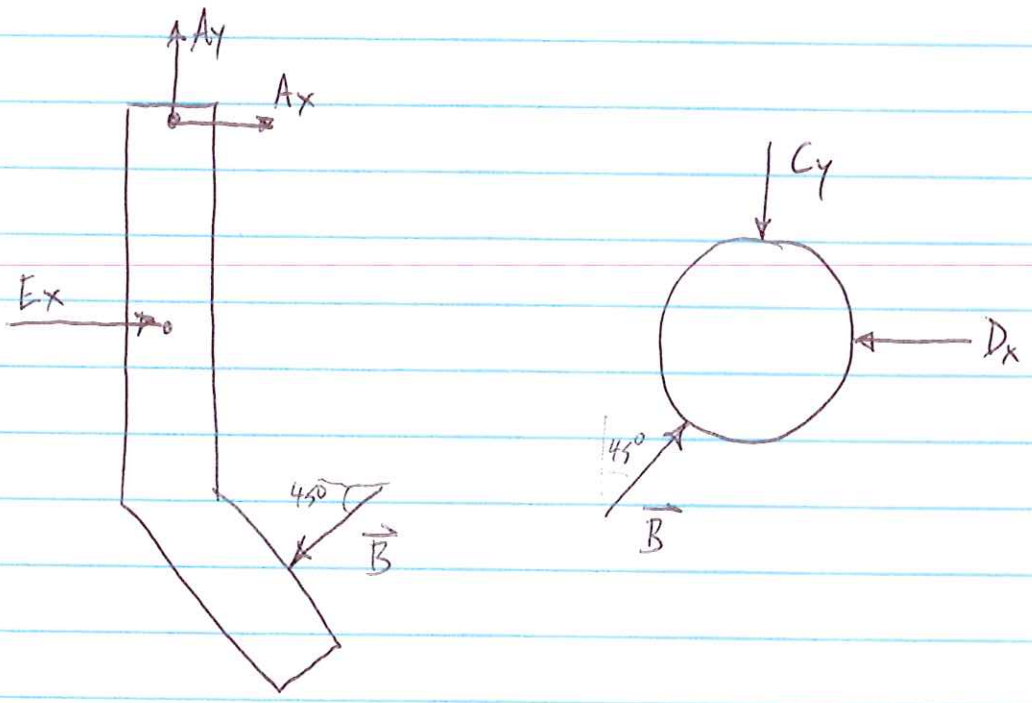
$d = 2.5\ \text{ft}$

$I_o = (117.8\ \text{SLUG}\cdot\text{ft}^2) + (26.34\ \text{SLUG})(2.5\ \text{ft})^2$

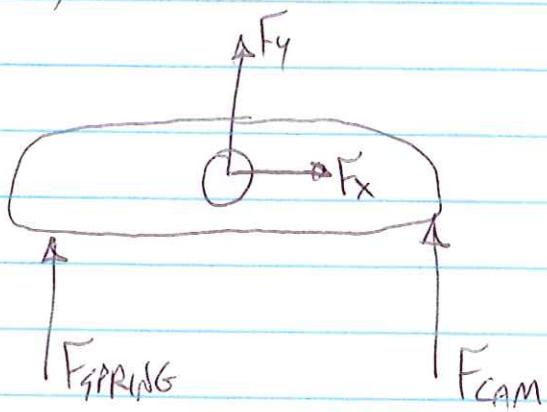
$I_o = 282.4\ \text{SLUG}\cdot\text{ft}^2$

9093 LB

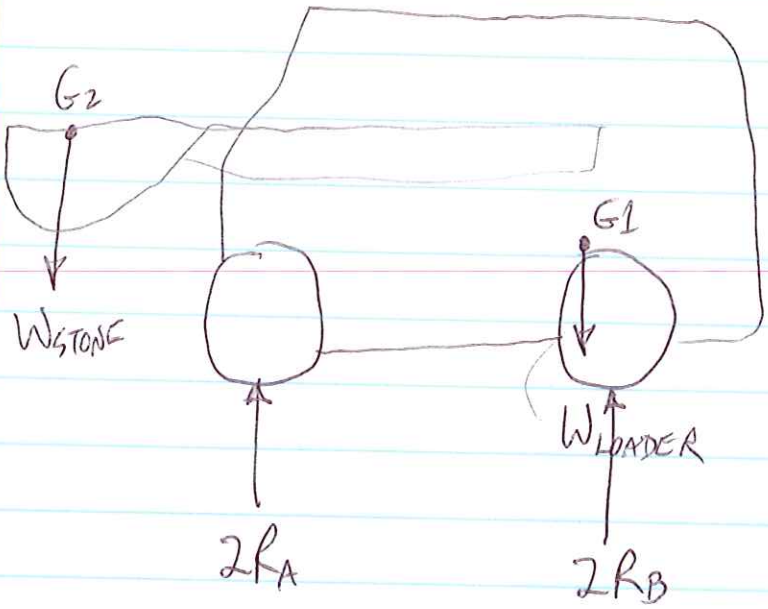
PROB. 4 a)

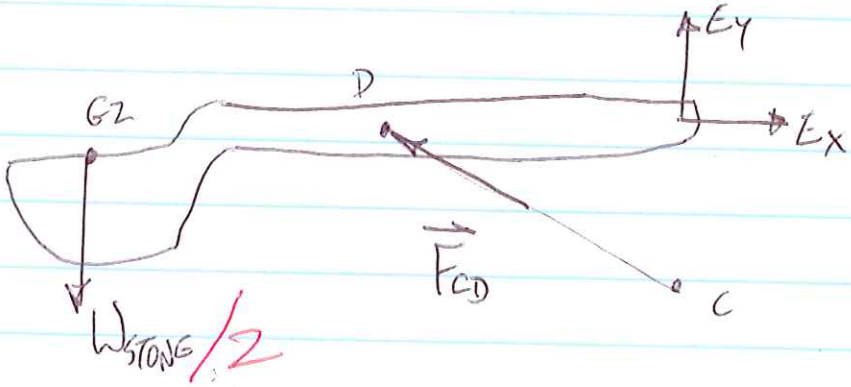


4 b)

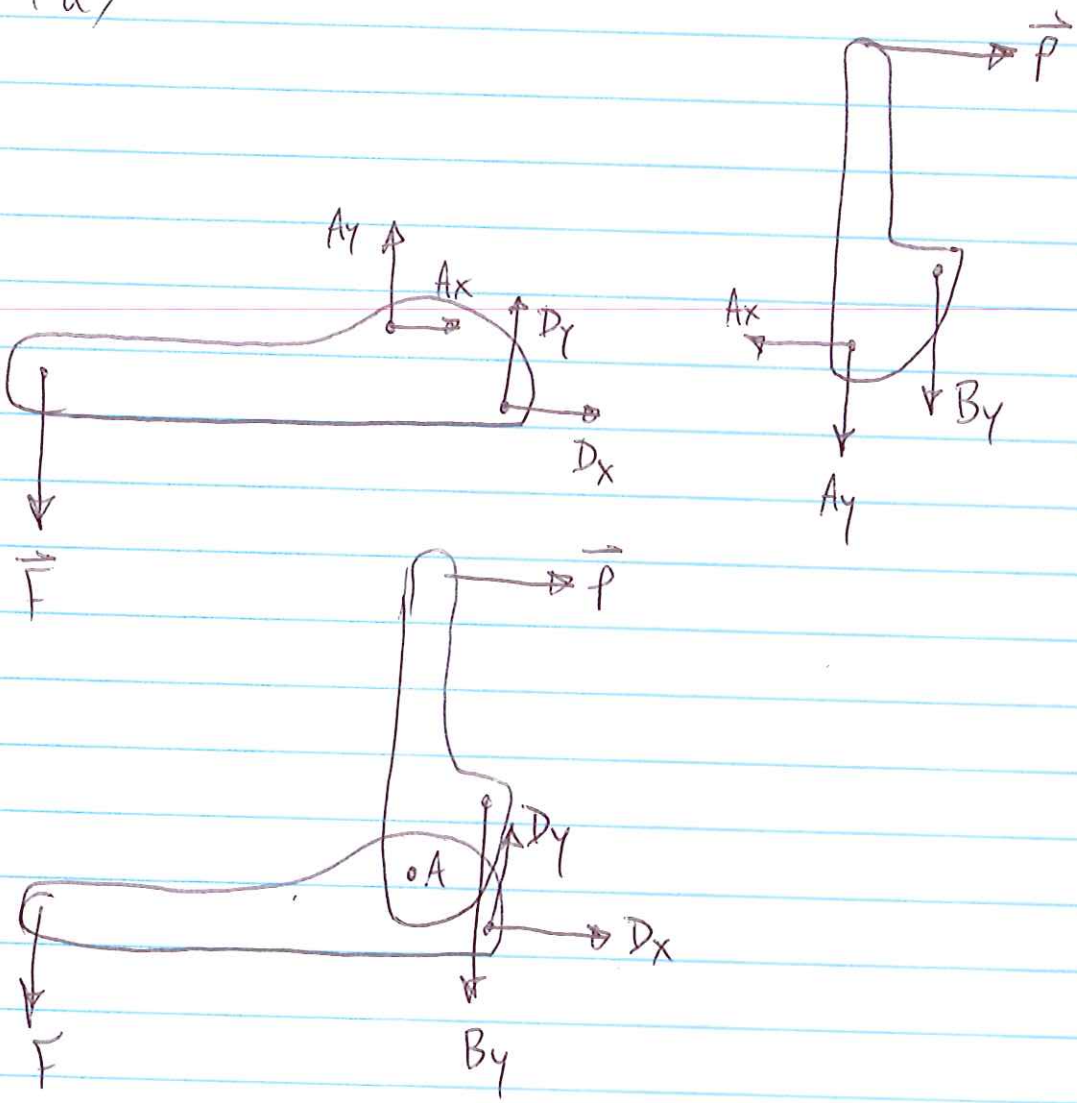


4 c)

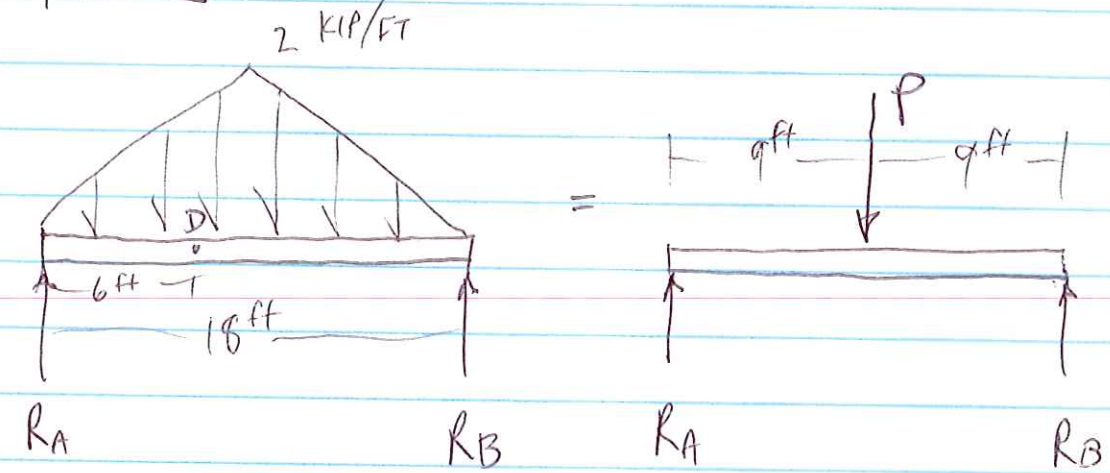




4 d)

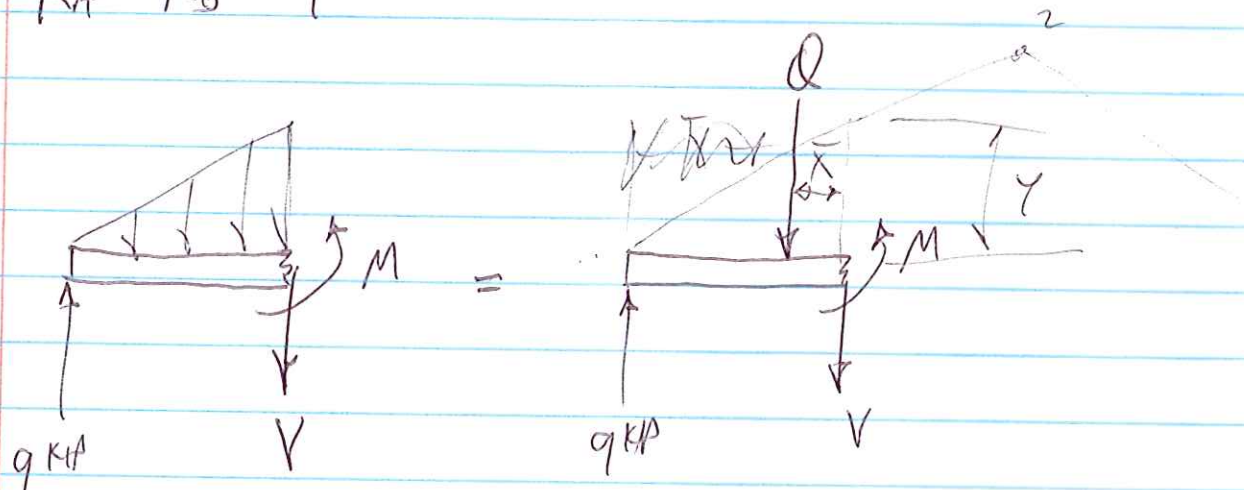


7.-22



$$P = \frac{1}{2}(18^{FT})(2^{KIP/FT}) = 18^{KIPS}$$

$$R_A = R_B = 9^{KIP}$$



~~$Q = \frac{1}{2}(6^{FT})(2^{KIP/FT})$~~

$$M = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{2-0}{9-0} = \frac{2}{9}^{KIP/FT} = \frac{2}{9}^{KIP/FT^2}$$

$$Y = MX \quad , \quad Y = \left(\frac{2}{9}^{KIP/FT^2}\right)(6^{FT}) = \frac{4}{3}^{KIP/FT}$$

$$Q = \frac{1}{2}(6^{FT})\left(\frac{4}{3}^{KIP/FT}\right) = 4^{KIPS}$$

$$\bar{X} = \frac{1}{3}h = \frac{1}{3}(6^{FT}) = 2^{FT}$$

7-22 CONT.

(12)

$\Sigma F_y = 0$: $9 - V - 4 = 0$, $V = 5$ KIPS

$\Sigma M = 0$:

$M + (2^{ft})(4^{KIP}) - (6^{ft})(9^{KIP}) = 0$

$M = 46^{ft \cdot KIP}$