Wright State University
Department of Mechanical and Materials Engineering

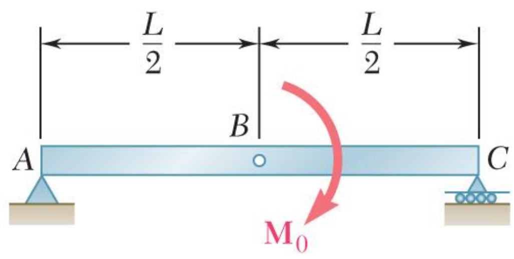
Spring 2017

ME 2120: STATICS

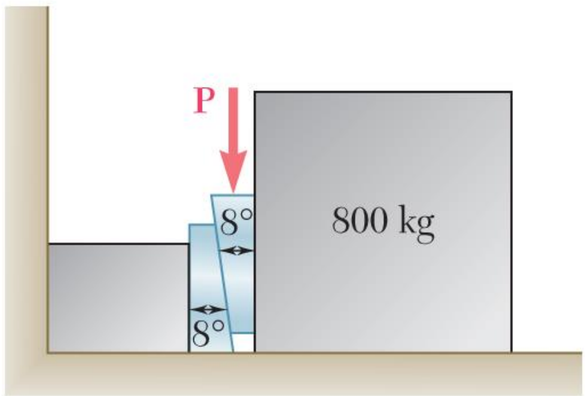
FINAL EXAM

OPEN BOOK, CLOSED NOTES, SHOW ALL WORK FOR PARTIAL CREDIT

Problem 1: (10 points) For the beam and loading shown, draw the shear and bending-moment diagrams, and determine the maximum absolute values of the shear and bending moment.



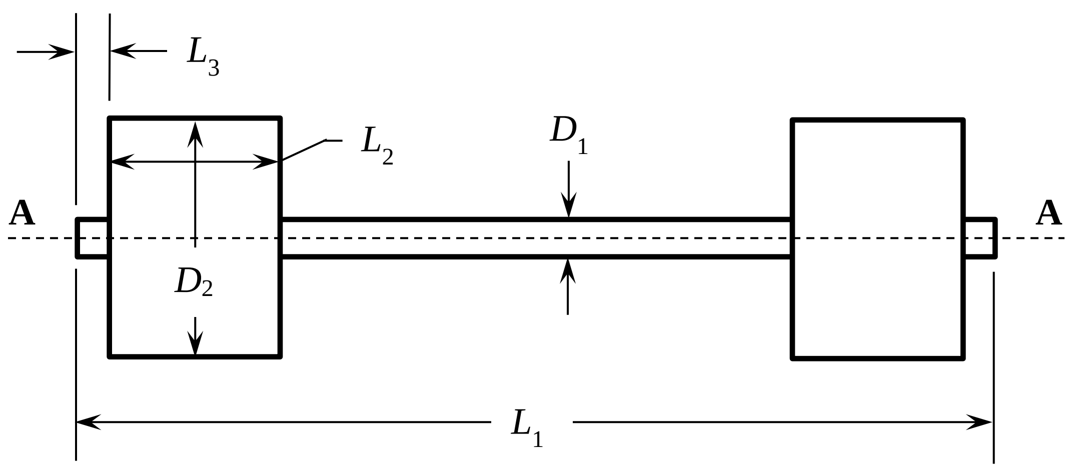
Problem 2: (10 points) Two 8° wedges of negligible weight are used to move and position the 800-block. Knowing that the coefficient of static friction is 0.30 at all surfaces of contact, determine the smallest force **P** that should be applied.



Problems 3 is on the back of this sheet.

Problem 3: (10 points) A weightlifting barbell is shown below. Determine the mass moment of inertia of the composite body about the axis of symmetry **AA** if the bar and the weights are all steel.

γ	0.2836 lb/in^3
L_1	30 in
L_2	3 in
L_3	2 in
D_1	1 in
D_2	5 in

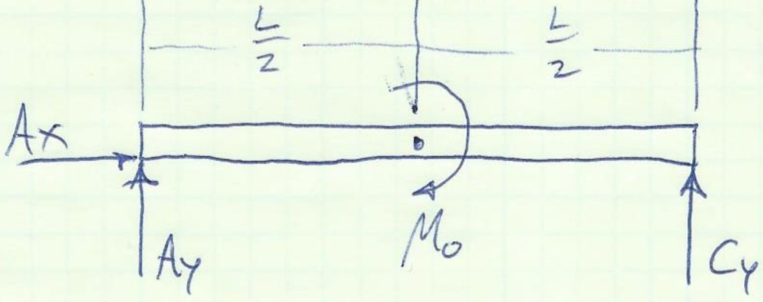


Not to scale

FINAL EXAM, SPRING 2017, STATICS

PROB. 1 (PROB. 7.33)

DRAW SHEAR, BENDING MOMENT DIAGRAMS, FIND V_{max}, M_{max}



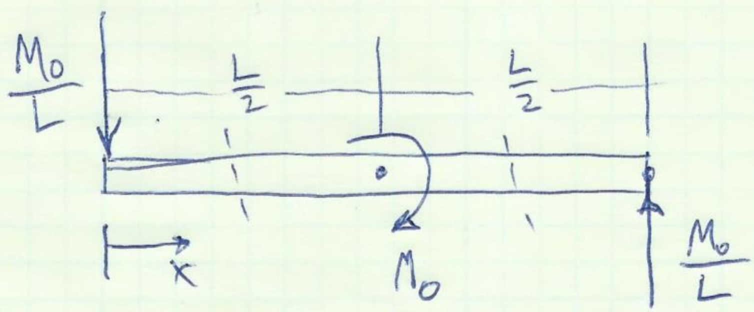
$\Sigma F_x = 0: \quad A_x = 0$

$\Sigma F_y = 0: \quad A_y + C_y = 0$

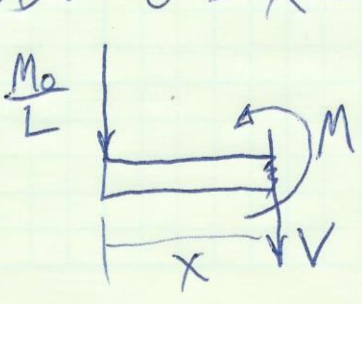
$\Sigma M_A = 0 \; (+\circlearrowleft): \quad -M_0 + L \cdot C_y = 0$

$$\boxed{C_y = \frac{M_0}{L}}$$

$$\boxed{A_y = -C_y = -\frac{M_0}{L}}$$



FBD: $0 \le x < \frac{L}{2}$



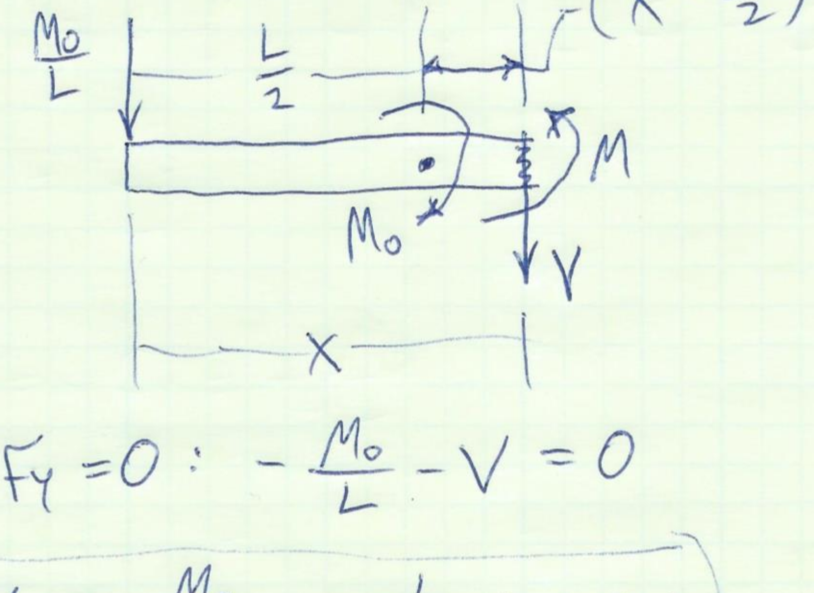
$$\sum F_y = 0: \; -\frac{M_0}{L} - V = 0$$

$$\boxed{V = -\frac{M_0}{L}, \quad 0 \le X < \frac{L}{2}}$$

$$\sum M_{CUT} = 0 \;\circlearrowleft{+}: \; \left(\frac{M_0}{L}\right)\cdot X + M = 0$$

$$\boxed{M = -\left(\frac{M_0}{L}\right)\cdot X, \quad 0 \le X < \frac{L}{2}}$$

FBD: $\frac{L}{2} < X \le L$



$$\sum F_y = 0: \; -\frac{M_0}{L} - V = 0$$

$$\boxed{V = -\frac{M_0}{L}, \quad \frac{L}{2} < X \le L}$$

$$\sum M_{CUT} = 0 \;\circlearrowleft{+}: \; \left(\frac{M_0}{L}\right)\cdot X - M_0 + M = 0$$

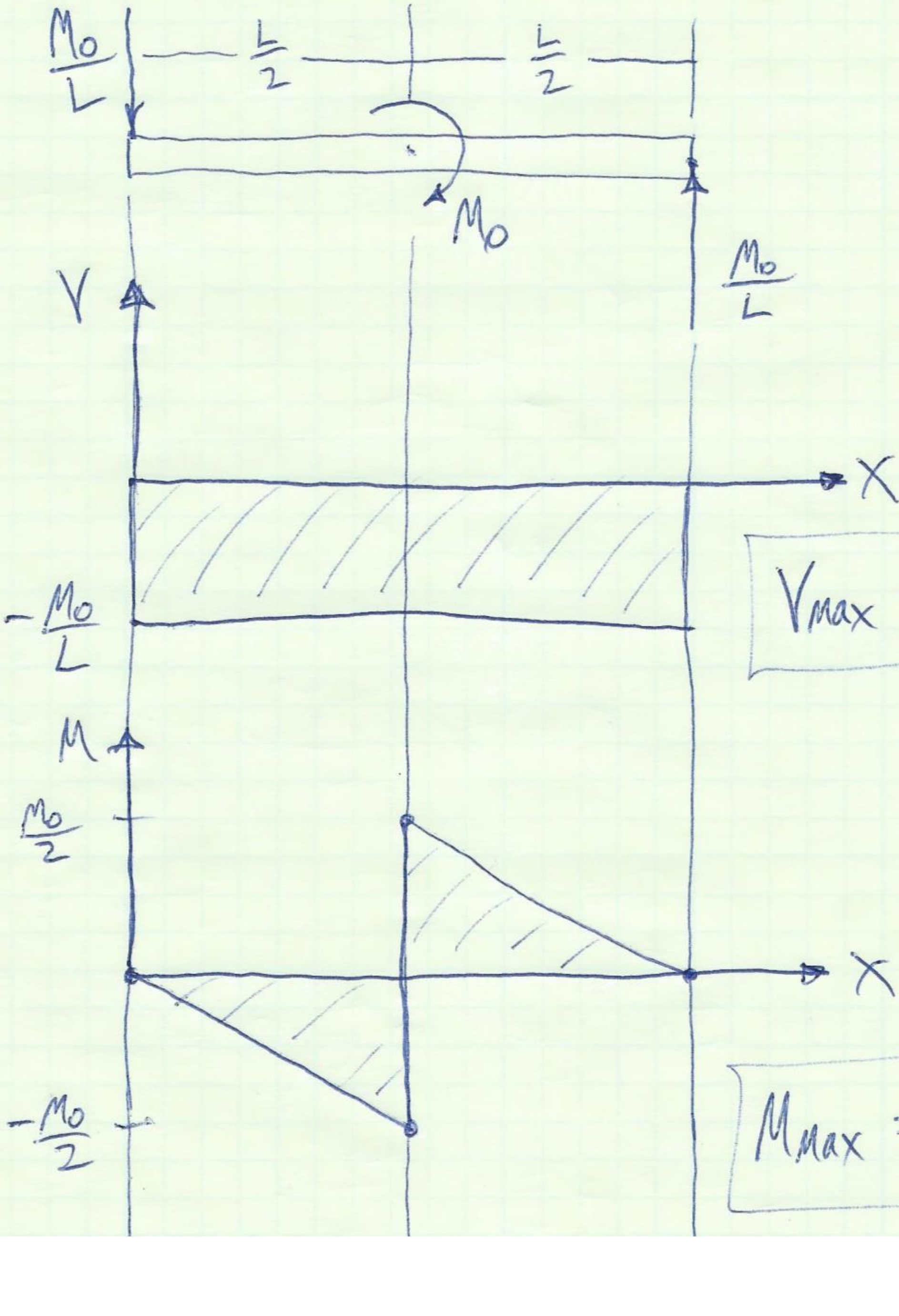
$$\boxed{M = M_0\left(1 - \frac{X}{L}\right), \quad \frac{L}{2} < X \le L}$$

BENDING MOMENT DIAGRAM:

$@\ x = 0,\ M = 0\ ;\quad @\ x = \frac{L}{2},\ M = -\left(\frac{M_0}{L}\right)\left(\frac{L}{2}\right) = -\frac{M_0}{2}$

$@\ x = \frac{L}{2},\ M = M_0\left[1 - \left(\frac{L}{2}\right)\left(\frac{1}{L}\right)\right] = \frac{M_0}{2}$

$@\ x = L,\ M = M_0\left[1 - \frac{L}{L}\right] = 0$

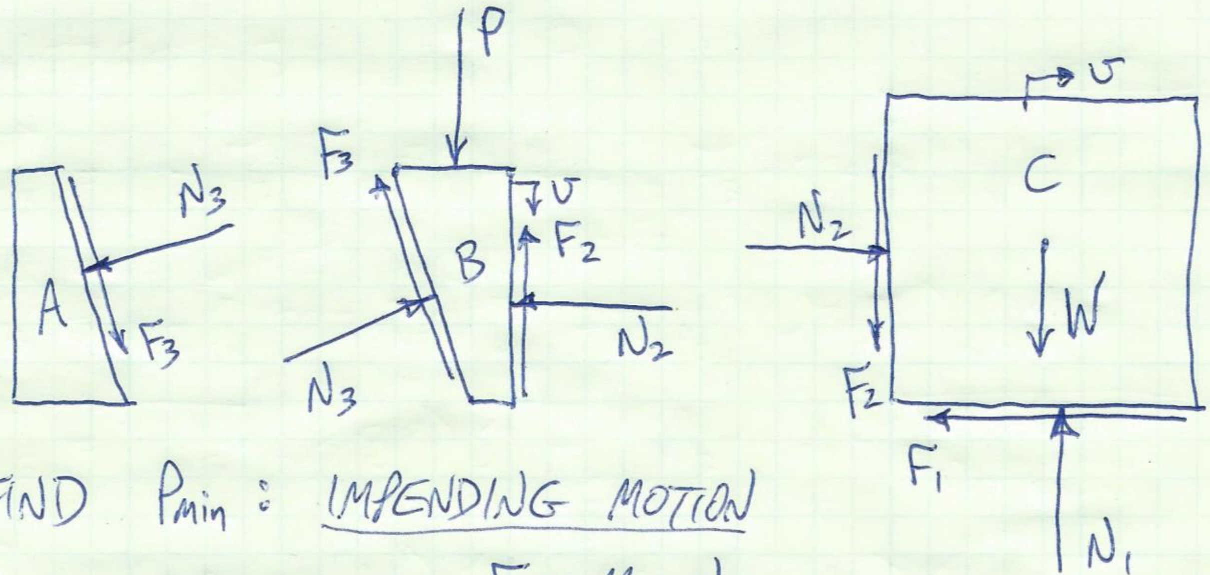


$\boxed{V_{max} = \frac{M_0}{L}}$

$\boxed{M_{max} = \frac{M_0}{2}}$

Problem 1 Scores:

10	9	8	7	6	5	4	3	2	1	0
2	1	2	4	6	4	6	4	5	6	4



FIND P_{min} : IMPENDING MOTION

$F = \mu_s \cdot N$

BLOCK C:

$\Sigma F_x = 0: \quad N_2 - F_1 = 0$

$N_2 = F_1 = \mu_s N_1$

$\boxed{N_2 = 0.3 N_1}$ ①

$\Sigma F_y = 0: \quad -F_2 - mg + N_1 = 0$

$-\mu_s \cdot N_2 - mg + N_1 = 0$

$N_1 = \mu_s N_2 + mg$

$N_1 = (0.3) N_2 + (800\ \mathrm{kg})(9.81\ \frac{m}{s^2})$

$\boxed{N_1 = 0.3 N_2 + 7848}$ ②

SUBSTITUTE ② INTO ①:

$$N_2 = 0.3(0.3N_2 + 7848)$$

$$N_2(1 - 0.3^2) = 0.3(7848)$$

$$\boxed{N_2 = 2587^{N}}$$

WEDGE B:

$$\vec{F_3} = (-F_3 \cdot \sin 8^\circ)\hat{i} + (F_3 \cdot \cos 8^\circ)\hat{j}\ ^{N}$$

$$\vec{F_3} = (-0.1392\,F_3)\hat{i} + (0.9903\,F_3)\hat{j}\ ^{N}$$

$$\vec{N_3} = (N_3 \cdot \cos 8^\circ)\hat{i} + (N_3 \cdot \sin 8^\circ)\hat{j}\ ^{N}$$

$$\vec{N_3} = (0.9903\,N_3)\hat{i} + (0.1392\,N_3)\hat{j}\ ^{N}$$

$$\Sigma F_x = 0:\ 0.9903\,N_3 - 0.1392\,F_3 - N_2 = 0$$

$$0.9903\,N_3 - 0.1392(0.3)\,N_3 = 2587$$

$$0.9485\,N_3 = 2587$$

$$\boxed{N_3 = 2727^{N}}$$

$$\Sigma F_y = 0:\ 0.1392\,N_3 + 0.9903\,F_3 + F_2 - P = 0$$

$$P = 0.1392\,N_3 + 0.9903\,(0.3)N_3 + (0.3)N_2$$

$$P = 0.1392\,(2727) + 0.9903\,(0.3)(2727) + (0.3)(2587)$$

$$\boxed{P = 1966^{N}}$$

Problem 2 Scores:

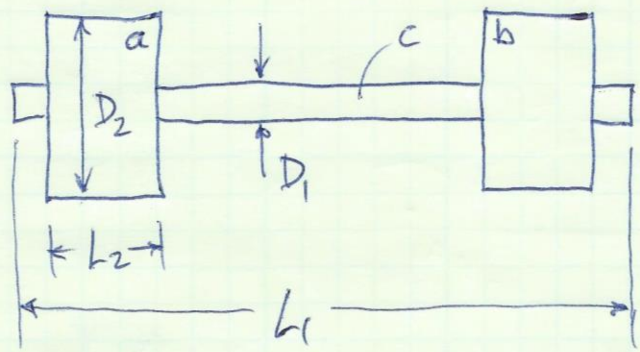
10	9	8	7	6	5	4	3	2	1	0
6	9	5	3	4	3	1	4	1	2	6

PROB. 3

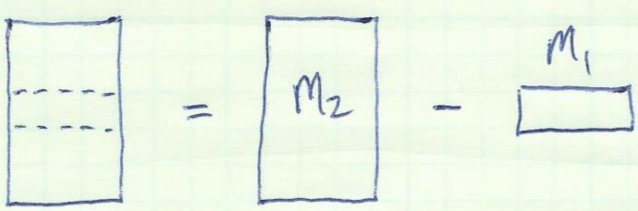
$\gamma = 0.2836 \frac{LB}{IN^3}$, $L_1 = 30^{IN}$, $L_2 = 3^{IN}$, $L_3 = 2^{IN}$

$D_1 = 1^{IN}$, $D_2 = 5^{IN}$

FIND $I_{AA} = I_a + I_b + I_c$



HOLLOW CYLINDER a:



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

$$I_a = \frac{1}{2} M_2 \left(\frac{D_2}{2}\right)^2 - \frac{1}{2} M_1 \left(\frac{D_1}{2}\right)^2 = \frac{1}{8}\left(M_2 D_2^2 - M_1 D_1^2\right)$$

$$M_2 = \frac{W_2}{g} = \frac{\gamma V_2}{g} = \frac{\gamma}{g} \cdot \frac{\pi}{4} D_2^2 L_2$$

$$M_2 = \frac{\pi}{4}\left(5^{IN}\right)^2 \left(3^{IN}\right)\left(\frac{0.2836 \frac{LB}{IN^3}}{32.2 \frac{ft}{s^2}}\right)$$

$$\boxed{M_2 = 0.5188 \frac{LB \cdot s^2}{ft}}$$

$$M_1 = \frac{W_1}{g} = \frac{\gamma V_1}{g} = \frac{\gamma}{g} \cdot \frac{\pi}{4} D_1^2 L_2$$

$$M_1 = \frac{\pi}{4} (1^{IN})^2 (3^{IN}) \left(\frac{0.2836 \frac{LB}{IN^3}}{32.2 \frac{ft}{s^2}} \right)$$

$$\boxed{M_1 = 0.02075 \frac{LB \cdot s^2}{ft}}$$

$$I_a = \frac{1}{8}\left[\left(0.5188 \frac{LB \cdot s^2}{ft}\right)\left(\frac{5}{12} ft\right)^2 - \left(0.02075 \frac{LB \cdot s^2}{ft}\right)\left(\frac{1}{12} ft\right)^2 \right]$$

$$\boxed{I_a = I_b = 0.01124 \ ft \cdot LB \cdot s^2}$$

CYLINDER C:

$$I_c = \frac{1}{2} M_c r_1^2 = \frac{1}{2} M_c \left(\frac{D_1}{2}\right)^2 = \frac{1}{8} M_c D_1^2$$

$$M_c = \frac{W_c}{g} = \frac{\gamma V_c}{g} = \frac{\gamma}{g} \cdot \frac{\pi}{4} D_1^2 L_1$$

$$M_c = \frac{\pi}{4} (1^{IN})^2 (30^{IN}) \left(\frac{0.2836 \frac{LB}{IN^3}}{32.2 \frac{ft}{s^2}} \right)$$

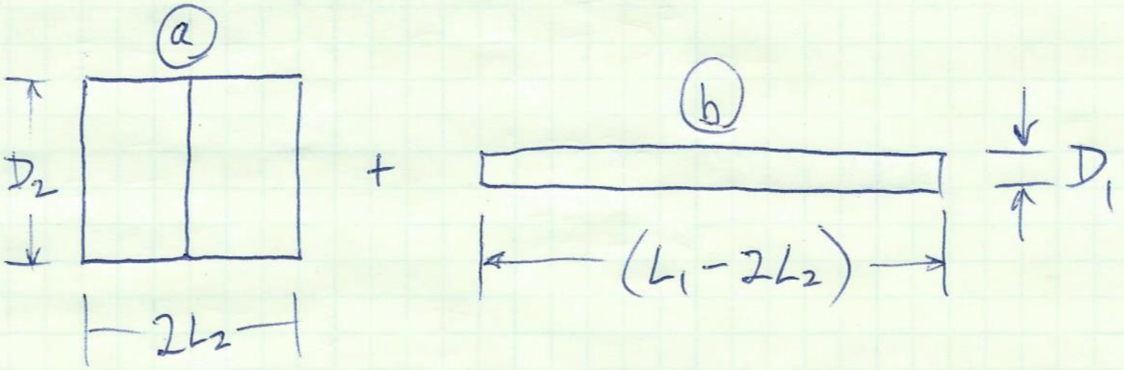
$$\boxed{M_c = 0.2075 \frac{LB \cdot s^2}{ft}}$$

$$I_c = \frac{1}{8}\left(0.2075 \frac{LB \cdot s^2}{ft}\right)\left(\frac{1}{12} ft\right)^2$$

$$\boxed{I_c = 1.801 \times 10^{-4} \ ft \cdot LB \cdot s^2}$$

$$I_{AA} = 2(0.01124) + 1.801 \times 10^{-4}$$

$$\boxed{I_{AA} = 0.02266 \ ft \cdot LB \cdot s^2}$$



$$I_{AA} = I_a + I_b$$

CYLINDER a:

$$I_a = \frac{1}{2} M_a r_a^2 = \frac{1}{2} M_a \left(\frac{D_2}{2}\right)^2 = \frac{1}{8} M_a D_2^2$$

$$M_a = \frac{W_a}{g} = \frac{\gamma V_a}{g} = \frac{\gamma}{g} \cdot \frac{\pi}{4} D_2^2 \cdot 2L_2 = \frac{\pi}{2} D_2^2 L_2 \cdot \frac{\gamma}{g}$$

$$M_a = \frac{\pi}{2} (5^{IN})^2 (3^{IN}) \left(\frac{0.2836 \frac{LB}{IN^3}}{32.2 \frac{ft}{s^2}}\right)$$

$$\boxed{M_a = 1.038 \frac{LB \cdot s^2}{ft}}$$

$$I_a = \frac{1}{8} \left(1.038 \frac{LB \cdot s^2}{ft}\right)\left(\frac{5}{12} ft\right)^2$$

$$\boxed{I_a = 0.02252 \; ft \cdot LB \cdot s^2}$$

CYLINDER b:

$$I_b = \frac{1}{2} M_b r_b^2 = \frac{1}{2} M_b \left(\frac{D_1}{2}\right)^2 = \frac{1}{8} M_b D_1^2$$

$$M_b = \frac{W_b}{g} = \frac{\gamma V_b}{g} = \frac{\gamma}{g} \cdot \frac{\pi}{4} D_1^2 (L_1 - 2L_2)$$

PROB. 3 ALT. (10)

$$m_b = \frac{\pi}{4}(1^{IN})^2\left[(30^{IN}) - 2(3^{IN})\right]\left(\frac{0.2836\ \frac{LB}{IN^3}}{32.2\ \frac{ft}{s^2}}\right)$$

$$\boxed{m_b = 0.1660\ \frac{LB \cdot s^2}{ft}}$$

$$I_b = \frac{1}{8}\left(0.1660\ \frac{LB \cdot s^2}{ft}\right)\left(\frac{1}{12}\ ft\right)^2$$

$$\boxed{I_b = 1.441 \times 10^{-4}\ ft \cdot LB \cdot s^2}$$

$$I_{AA} = \left(0.02252 + 1.441 \times 10^{-4}\ ft \cdot LB \cdot s^2\right)$$

$$\boxed{I_{AA} = 0.02266\ ft \cdot LB \cdot s^2}$$

Problem 3 Scores:

10	9	8	7	6	5	4	3	2	1	0
3	8	6	6	2	3	3	2	9	1	1