ME 270 – Fall 2016 FINAL EXAM NAME (Last, First): ________________________________

Please indicate your group number ____________ (If applicable)

Instructor's Name and Section: ______________________________

Circle One:

MWF 8:30-9:20 AM	V Zeinoddini Meimand	MWF 2:30-3:20 PM	J Ackerman
MWF 9:30-10:20 AM	J Jones	MWF 4:30-5:30 PM	A Buganza Tepole
MWF 11:30-12:20 PM	D Hoyniak	TTH 9:00-10:15 AM	M Murphy
MWF 12:30-1:20 PM	I Bilionis	J Jones Distance Learning	

Please review the following statement:

I certify that I have not given unauthorized aid nor have I received aid in the completion of this exam.

Signature: ______________________________________

INSTRUCTIONS

Begin each problem in the space provided on the examination sheets. If additional space is required, use the white lined paper provided to you.

Work on one side of each sheet only, with only one problem on a sheet.

Each problem is worth 25 points.

Please remember that for you to obtain maximum credit for a problem, it must be clearly presented, i.e.

- The only authorized exam calculator is the TI-30IIS
- The allowable exam time for the FINAL EXAM is 120 minutes.
- The coordinate system must be clearly identified.
- Where appropriate, free body diagrams must be drawn. These should be drawn separately from the given figures.
- Units must be clearly stated as part of the answer.
- You must carefully delineate vector and scalar quantities.

If the solution does not follow a logical thought process, it will be assumed in error.

When handing in the test, please make sure that all sheets are in the correct sequential order and make sure that your name is at the top of every page that you wish to have graded.

Problem 1 __________

Problem 2 __________

Problem 3 __________

Problem 4___________

TOTAL ____________

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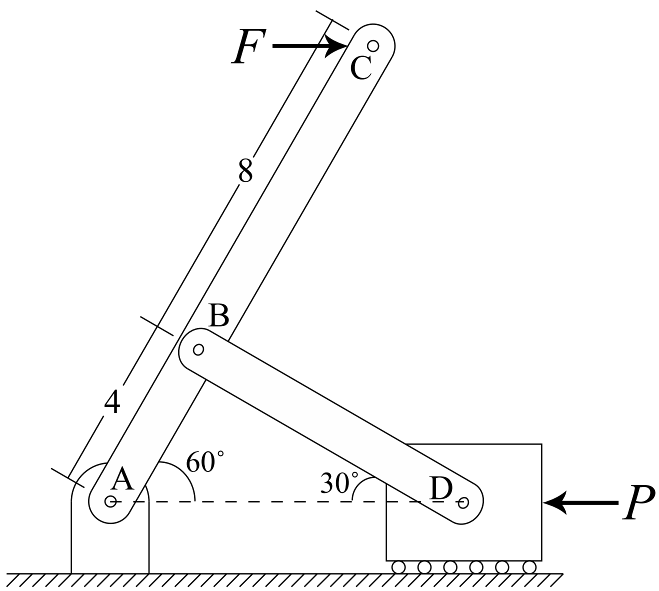
PROBLEM 1. (25 points) These questions are all or nothing

Consider the can crusher shown in the figure. All dimensions are in inches. The crusher is made of stainless steel (see table for its mechanical properties). The support at A is a doubly-connected pin joint. The connections at B and D are also doubly connected pin joints. The pins are all made of stainless steel. The box D can roll without friction with respect to the ground. You may ignore the weight of each part of the can crasher. The input force F and the output force P are not specified at this point.

The crusher will be used to crush aluminum soda cans. The force required to crush a perfectly preserved (and empty) aluminum can is P=234 lbs (it is much easier to crush an empty can that has been pre-buckled!). The problem has two goals: (1) Calculate the minimum input force F we need so that the crusher performs its purpose without a problem, and (2) Design the dimensions of the members so that it can withstand the worst-case scenario.

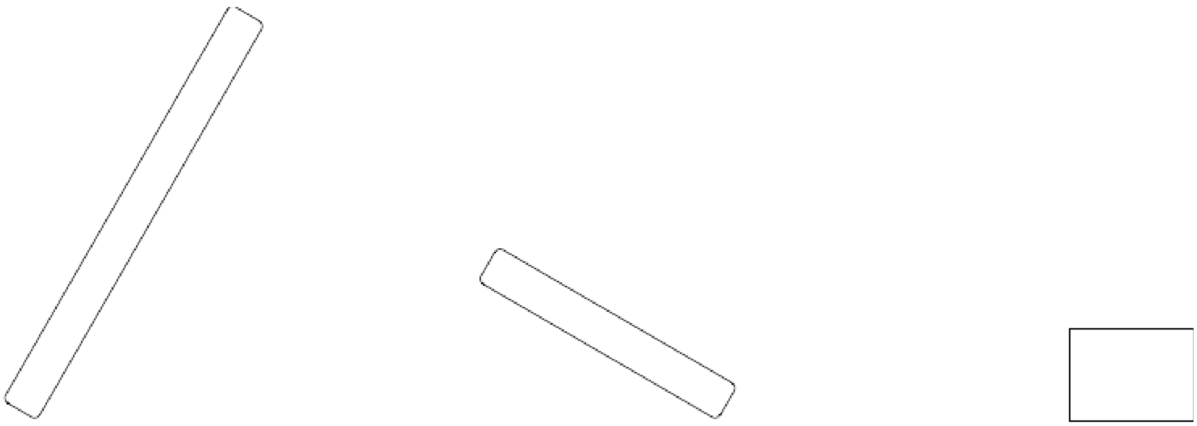


Property	**Value in US units**
Ultimate Tensile Strength	70 ksi
Ultimate Compressive Strength	25 ksi
Ultimate Shear Strength	42 ksi
Young Modulus	29,000 ksi
Shear Modulus	11,600 ksi
Poisson's Ratio	0.27

1A. List all two force members of the machine.

Two force members: (1 pts)

1B. Draw the FBD of each one of the member of the machine (6 pts).



1C. Calculate the minimum input force required to crush a perfect can. Show all your work.

$F =$ (4 pts)

1D. What is the axial force that develops inside member BD?

F_{BD} =_____________________	(1 pts)

1E. Is member BD under compression or under tension? Circle the right answer.

Member BD is under:	**Compression**	**Tension**	(1 pts)

1F. Using a factor of safety equal to 1.5, what should the cross-section area of member BD be?

A_{BD} =_____________________	(4 pts)

1G. Calculate the <u>magnitude</u> of the support reactions at A.

F_A =_____________________	(3 pts)

1H. At which pin(s) do you get the maximum shear stress? Circle the right answer. You may circle two or more if necessary.

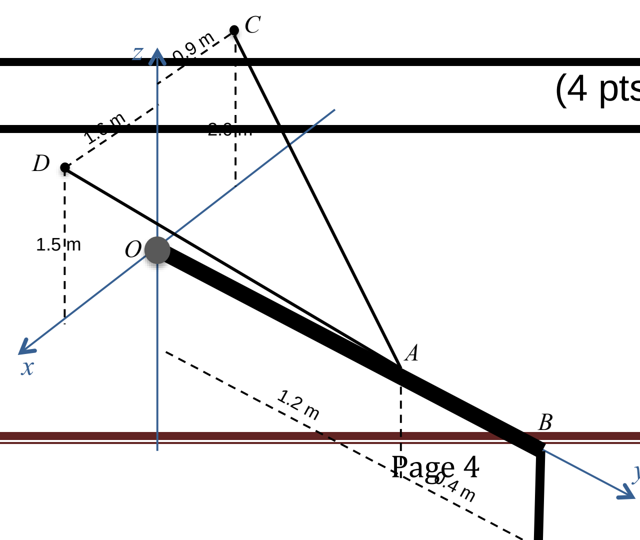
Maximum shear stress appears in pin:	**A**	**B**	**D**	(1 pts)

1I. Using a factor of safety equal to 1.5, what diameter would you pick for the pin(s) of question 1H?

Pin diameter:	(4 pts)

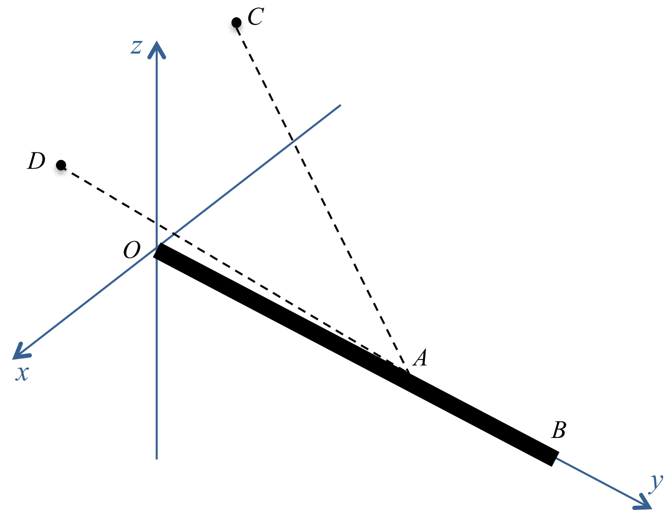
PROBLEM 2. (25 points)

Given: A mass-less boom is used to support a load (**W=819 N**) applied at point B. The boom is attached to the wall at point O with a ball and socket and supported by two cables at point A.



Find:

2A. Complete the **free-body diagram** for the boom on the figure provided. (4 points)



2B. Express the tension in cables (**T_{AC}** and **T_{AD}**) in terms of their **known unit vectors** and **unknown magnitudes**. (6 points)

$\overline{T_{AC}}$ =	(3 pts)
$\overline{T_{AD}}$ =	(3 pts)

2C. Determine the **magnitude of the tension** in cables. (6 points)

$\left\lvert \overline{T_{AC}} \right\rvert$ **=**	(3 pts)
$\left\lvert \overline{T_{AD}} \right\rvert$ **=**	(3 pts)

3D. Determine the **reactions at point O** and express them as a vector force. (6 points)

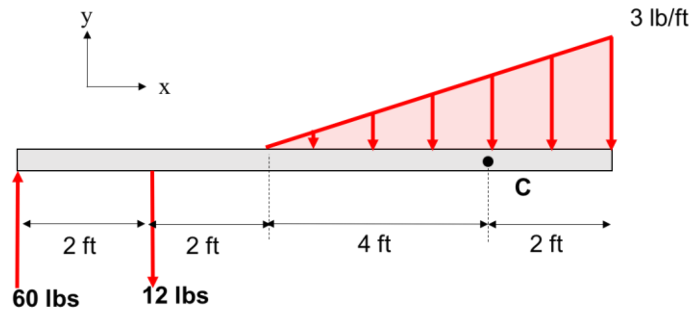
Reaction at O**=**	$\bar{i}$ **+**	$\bar{j}$ **+**	$\bar{k}$	(6 pts)

4D. Cable AC or AD can **support a maximum tension of 1200 N** before they fail. Determine the **maximum load (W)** that can be suspended from the end of the boom (3 pts):

W **=**	(3 pts)

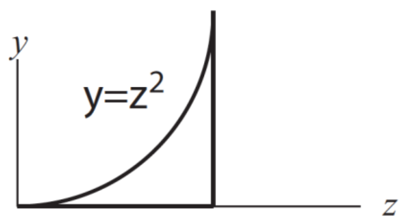
PROBLEM 3. (25 points) These questions are all or nothing

3A. Given the beam and loading depicted in the figure, determine the equivalent force-couple system at point C? (Hint: this is not a static equilibrium problem)



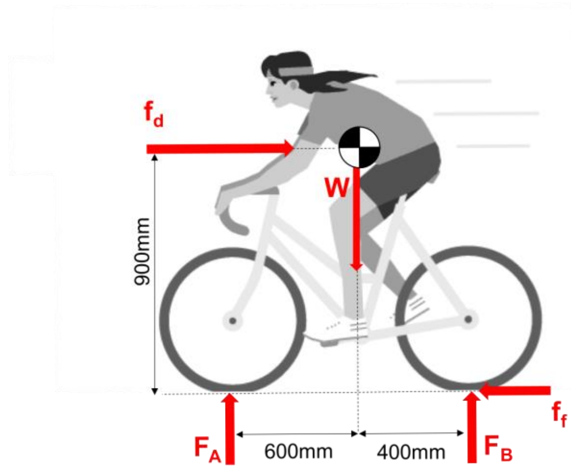
$\boldsymbol{F_C} =$ _____ $\bar{\boldsymbol{\imath}}$ + _____ $\bar{\boldsymbol{\jmath}}$	(3 pts)
$\boldsymbol{M_C} =$ ______ $\bar{\boldsymbol{k}}$	(2 pts)

3B. The enclosed shape shown below is bounded by z=0, z=1, y=0, and y=z². The y-coordinate of the centroid of the shape is y_c = 3/10. Calculate the second moment of area I_z with respect to the z-axis, and with respect to the axis passing through the centroid I_{zC}



$\boldsymbol{I_Z} =$ _______________	(2 pts)
$\boldsymbol{I_{zC}} =$ _____________	(3 pts)

3C. The figure shows a cyclist attempting to start a ride during a storm. The combined cyclist-bike weight is 700N. The friction coefficient of the rear tire with the pavement is μ=0.3. There is no friction at the front tire. What is the maximum wind resistance $\mathbf{f}_d$ that the cyclist can withstand without slipping? And for tipping? If the wind is extreme, what will happen first, slipping or tipping?

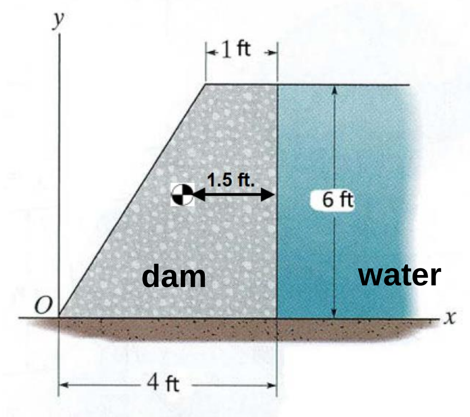


$f_{d,slip}$ = ____________ (2 pts)

$f_{d,tip}$ = ____________ (2 pts)

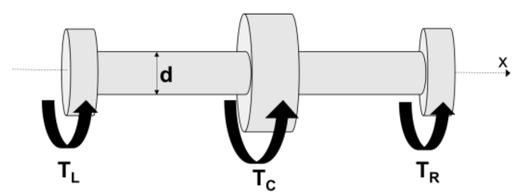
Slipping or tipping? ______________________ (1pt)

3D. Determine the magnitude of the hydrostatic force F_{eq} acting on the concrete dam. Assume $\rho g = 62.5\ lb/ft^3$, and the dam is 3 ft wide (into the page). What is the minimum weight of the concrete dam W_D needed to prevent the dam from tipping assuming the center of mass is as shown.



$\boldsymbol{F_{eq}} =$ ________________	(3 pts)
$\boldsymbol{W_D} =$ ________________	(2 pts)

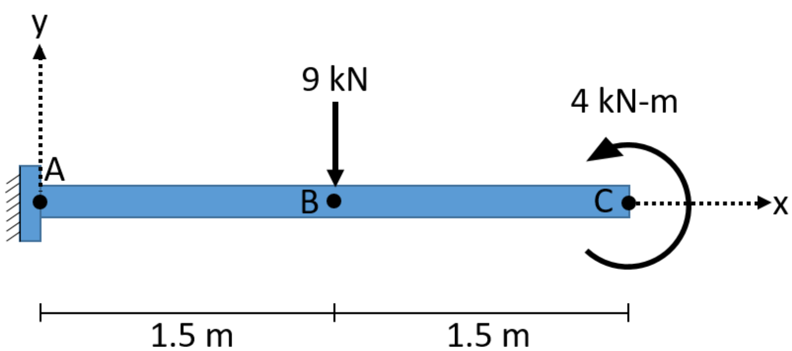
3E. The figure shows the shaft of the crank of a bicycle rotating at constant angular speed. The torque from the right pedal is **T**$_R$ = -36 N-m **i**, the torque from the left pedal is **T**$_L$ = - 1 N-m **i** . Determine the torque of the chain **T**$_C$. Determine the maximum shear stress on the shaft due to torsion if d=25mm.

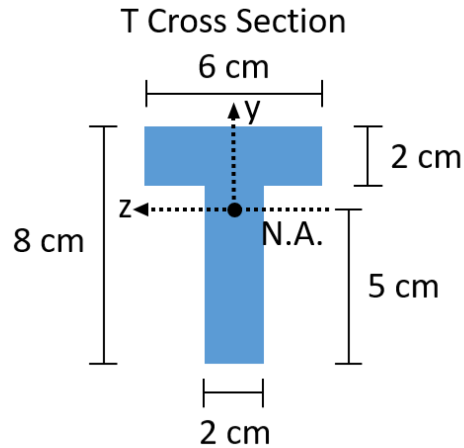


$\boldsymbol{T_C} =$ ____________ $\bar{\imath}$	(3 pts)
$\boldsymbol{\tau} =$ ______________	(2 pts)

PROBLEM 4. (25 points)

GIVEN: Consider the aluminum beam ABC with the given external loads shown in the figure below. The support at **A is a fixed support**. The beam has a **T cross section** with the cross section shown below.





FIND:

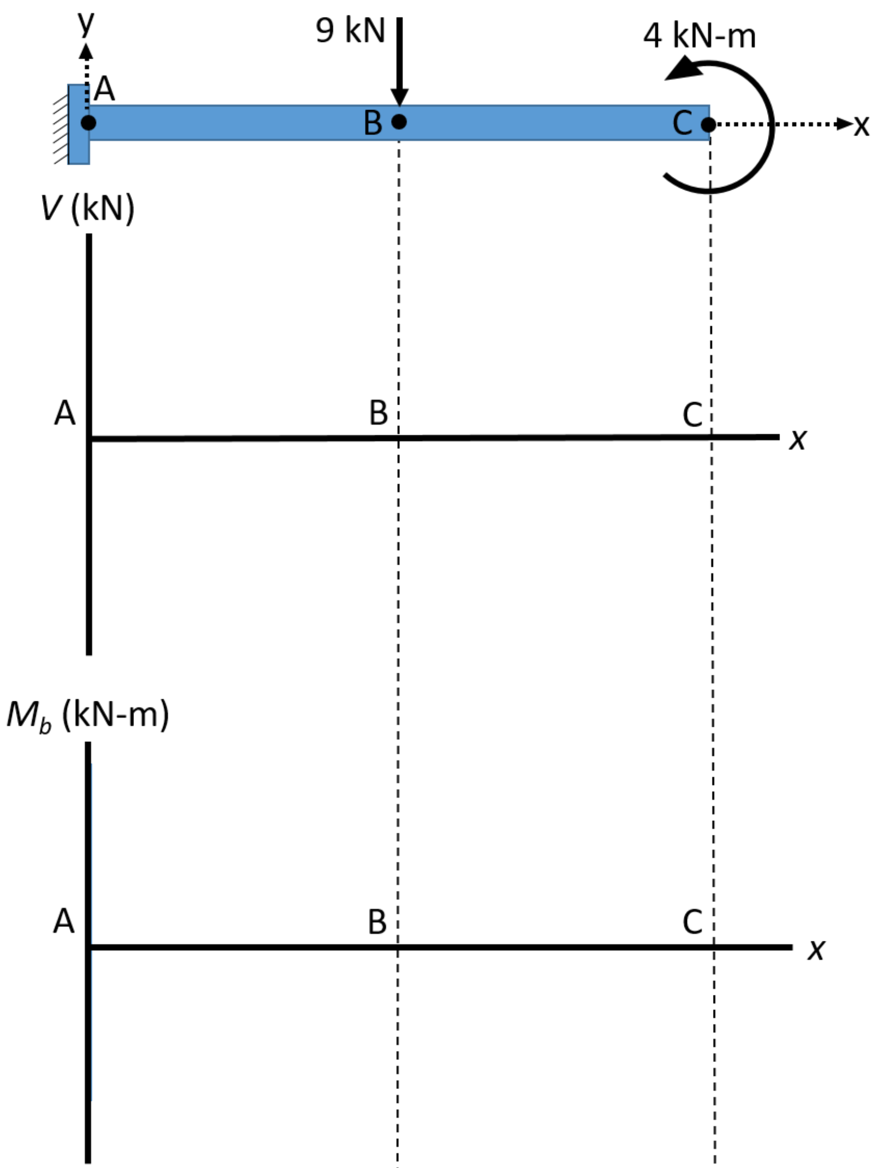
4A. Draw the **free body diagram** of the beam ABC and **calculate the reaction forces at the support** (3 pts).

A_x = ___________________________

A_y = ___________________________ (3 pts)

M_A = ___________________________

4B. Draw the **shear force and bending moment diagram** of the beam ABC. You must **label** the **shear force** and **bending moment values** on the diagram at points **A, B, and C** to receive full credit (5 pts). You may use the graphical method.



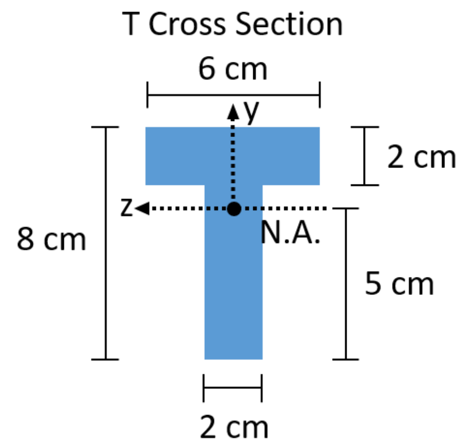
4C. Over what **section** is the beam in **pure bending** (1 pt)?

Section _____________ (1 pt)

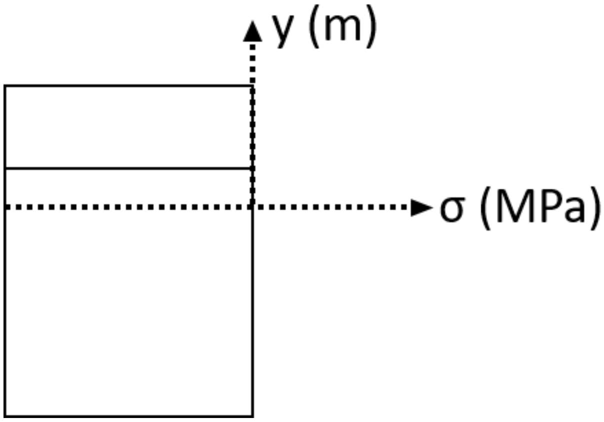
4D. Label the point in the diagram that experiences **pure shear**, and **write the x value** below (2 pt).

X Location of Point that Experiences Pure Shear ___________________________ (2 pt)

4E. Calculate the **second area moment of inertia about the z axis (I_z) at the given centroid**. Recall the T cross section of the beam shown on the right. Calculate the **normal stress at the TOP and BOTTOM of the beam (σ_{top} and σ_{bot}) in the section where pure bending occurs**. Calculate the corresponding **axial strain at the TOP and BOTTOM of the beam (ε_{top} and ε_{bot}).** For aluminum, the Young's Modulus E=69 GPa and the Shear Modulus G=27 GPa. Finally, **label the normal stress distribution for the side view of the section of the beam in pure bending shown on the next page (use the given axes)**. Your answers should include the **correct magnitude, sign, and units** (14 pt).



Label the stress distribution in the pure bending section below (use given axes):



I_z = ______________________________	(4 pt)
σ_{top} = ______________________________	(3 pt)
σ_{bot} = ______________________________	(3 pt)
ε_{top} = ______________________________	(1 pt)
ε_{bot} = ______________________________	(1 pt)
Labeled stress distribution on figure above this answer box	(2 pt)

1A. **BD**
1B. **Free Body Diagram**
1C. $\boldsymbol{F = 104\ lbs}$
1D. $\boldsymbol{F_{BD} = 270.2\ lbs}$
1E. **Compression**
1F. $\boldsymbol{A_{BD} = 0.0162\ in^2}$
1G. $\boldsymbol{F_A = 187.5\ lbs}$
1H. **B and D**
1I. **0.0783in**

2A. **Free Body Diagram**
2B. $\boldsymbol{T_{AC} = |\vec{T}_{AC}|(-0.36\ \hat{\imath} - 0.48\ \hat{\jmath} + 0.8\ \hat{k})}$
$\boldsymbol{T_{AD} = |\vec{T}_{AD}|(0.64\ \hat{\imath} - 0.48\ \hat{\jmath} + 0.6\ \hat{k})}$
2C. $\boldsymbol{|\overline{T_{AC}}| = 960N}$ $\boldsymbol{|\overline{T_{AD}}| = 540N}$
2D. $\boldsymbol{0\ \bar{\imath} + 720\ \bar{\jmath} + (-273)\ \bar{k}}$
2E. $\boldsymbol{W = 1023.75N}$

3A. $\boldsymbol{F_C = 0\ \bar{\imath} + 39\ \bar{\jmath}\ lbs}$ $\boldsymbol{M_C = -408\ \bar{k}\ lbs - ft}$
3B. $\boldsymbol{I_Z = 1/21 = 0.047}$ $\boldsymbol{I_{ZC} = 37/2100 = 0.017}$
3C. $\boldsymbol{F_{d,slip} = 172.6N}$ $\boldsymbol{F_{d,tip} = 311.11N}$ **Slipping**
3D. $\boldsymbol{F_{eq} = -3375\ lbs}$ $\boldsymbol{W_D = 2700\ lbs}$
3E. $\boldsymbol{T_C = 37N - m\ \bar{\imath}}$ $\boldsymbol{\tau = 11.73MPa}$

4A. **Free Body Diagram**
$\boldsymbol{A_X = 0kN}$ $\boldsymbol{A_y = 9kN}$ $\boldsymbol{M_A = 8\ kN - m}$
4B. **Shear Force and Bending Diagram**
4C. **BC**
4D. **1m**
4E. $\boldsymbol{I_z = 1.36x10^{-6}m^4}$ $\boldsymbol{\sigma_{top} = -88.2MPa}$ $\boldsymbol{\sigma_{bot} = 147MPa}$
$\boldsymbol{\varepsilon_{top} = -1.28x10^{-3}}$ $\boldsymbol{\varepsilon_{bot} = 2.13x10^{-3}}$

Fall 2016 Final Exam – Equation Sheet

Normal Stress and Strain

$$\sigma_x = \frac{F_n}{A}$$

$$\sigma_x(y) = \frac{-My}{I}$$

$$\varepsilon_x = \frac{\sigma_x}{E} = \frac{\Delta L}{L}$$

$$\varepsilon_y = \varepsilon_z = -\vartheta\varepsilon_x$$

$$\varepsilon_x(y) = \frac{-y}{\rho}$$

$$FS = \frac{\sigma_{fail}}{\sigma_{allow}}$$

Shear Stress and Strain

$$\tau = \frac{V}{A}$$

$$\tau(\rho) = \frac{T\rho}{J}$$

$$\tau = G\gamma$$

$$G = \frac{E}{2(1+\vartheta)}$$

$$\gamma = \frac{\delta_s}{L_s} = \frac{\pi}{2} - \theta$$

Second Area Moment

$$I = \int_A y^2 dA$$

$$I = \frac{1}{12}bh^3 \qquad \text{Rectangle}$$

$$I = \frac{\pi}{4}r^4 \qquad \text{Circle}$$

$$I_B = I_O + A{d_{OB}}^2$$

Polar Area Moment

$$J = \frac{\pi}{2}r^4 \qquad \text{Circle}$$

$$J = \frac{\pi}{2}(r_o^4 - r_i^4) \quad \text{Tube}$$

Shear Force and Bending Moment

$$V(x) = V(0) + \int_0^x p(\epsilon)d\epsilon$$

$$M(x) = M(0) + \int_0^x V(\epsilon)d\epsilon$$

Buoyancy

$$F_B = \rho g V$$

Fluid Statics

$$p = \rho g h$$

$$F_{eq} = p_{avg}(Lw)$$

Belt Friction

$$\frac{T_L}{T_S} = e^{\mu\beta}$$

Distributed Loads

$$F_{eq} = \int_0^L w(x)dx$$

$$\bar{x}F_{eq} = \int_0^L x\, w(x)dx$$

Centroids

$$\bar{x} = \frac{\int x_c dA}{\int dA} \qquad \bar{y} = \frac{\int y_c dA}{\int dA}$$

$$\bar{x} = \frac{\sum_i x_{ci}A_i}{\sum_i A_i} \qquad \bar{y} = \frac{\sum_i y_{ci}A_i}{\sum_i A_i}$$

In 3D, $\bar{x} = \frac{\sum_i x_{ci}V_i}{\sum_i V_i}$

Centers of Mass

$$\tilde{x} = \frac{\int x_{cm}\rho dA}{\int \rho dA} \qquad \tilde{y} = \frac{\int y_{cm}\rho dA}{\int \rho dA}$$

$$\tilde{x} = \frac{\sum_i x_{cmi}\rho_i A_i}{\sum_i \rho_i A_i} \qquad \tilde{y} = \frac{\sum_i y_{cmi}\rho_i A_i}{\sum_i \rho_i A_i}$$