ME 270 – Spring 2015 Final **NAME (Last, First): ______________________________**

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 20 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 Exam 1 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.

Instructor's Name and Section:

Sections: J Jones 9:30-10:20AM I Bilionis 1:30-2:20PM J Ackerman 3:30-4:20PM
J Jones Distance Learning

Problem 1 __________

Problem 2 __________

Problem 3 __________

Problem 4 __________

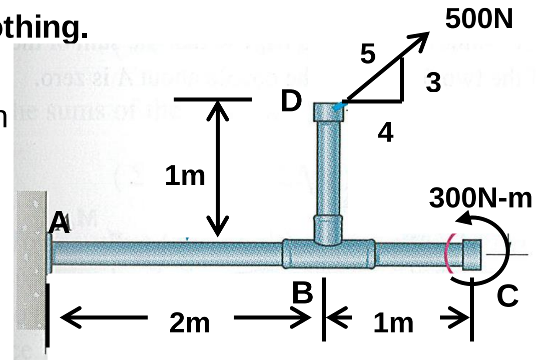
Problem 5 __________

Total ______________

ME 270 – Spring 2015 Final **NAME (Last, First):** ____________________

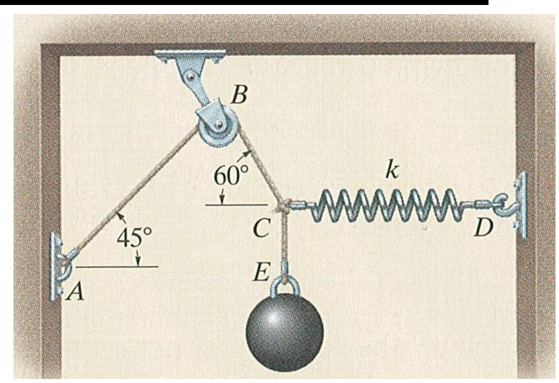
PROBLEM 1 (20 points). – Problem 1 questions are all or nothing. Please show all work.

1a. Bar ABCD is loaded with a single force and couple as shown and is held in static equilibrium by the fixed support at A. Determine the support reactions at A in vector form.



$\bar{F}_A =$	(2 pts)
$\bar{M}_A =$	(3 pts)

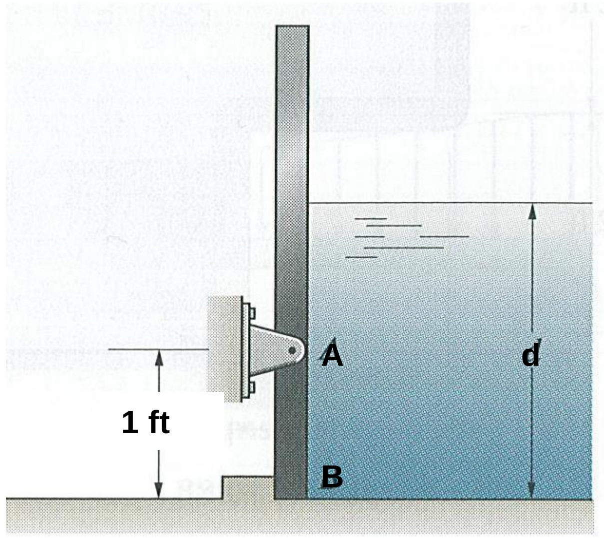
1B. Sphere E is held in static equilibrium with the cable system shown. Assuming the spring (CD) carries a load of 50lbs, determine the weight of the sphere (W_S) and the tension in cable CBA (T_{CBA}). Assume pulley B is frictionless.



$W_S =$	(2 pts)
$T_{CBA} =$	(3 pts)

Cont. Problem 1.

1C. The 1-foot wide gate shown is designed to rotate and release the water when the depth (d) exceeds a certain value. Write an expression for the water pressure at B in terms of depth "d". At what depth (d) will the gate just begin to open. Assume ρg for water is $62.4\ \frac{\text{lb}}{\text{ft}^2}$.



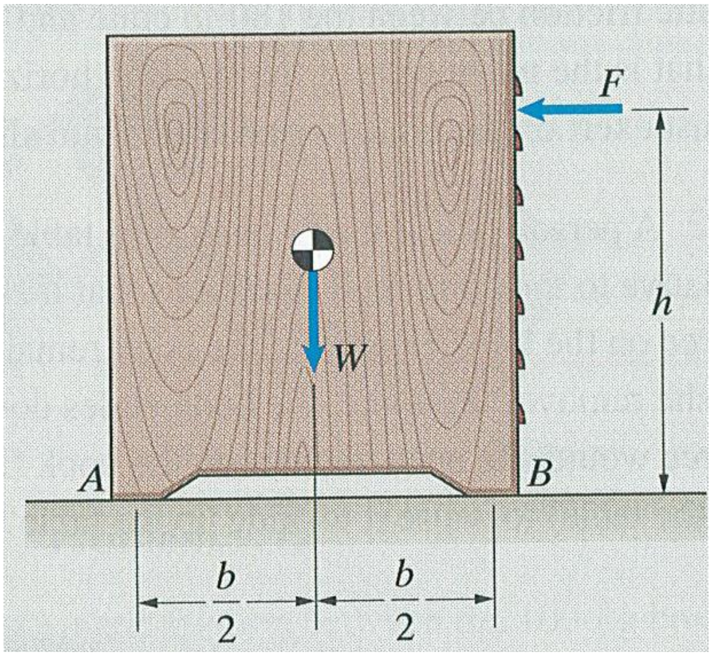
p_B =

d =

Cont. Problem 1.

1D. The chest shown has a weight (W) and is to be moved by force (F). Assuming the coefficient of friction between the chest and the floor is μ_s,

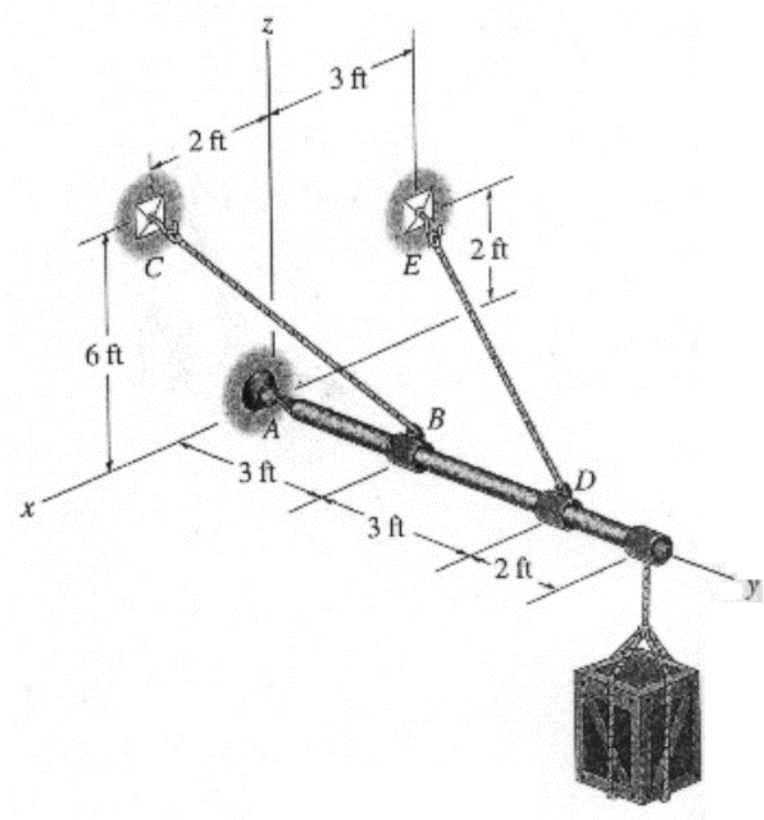
a) determine an expression for the tipping force (F_T) in terms of the variables W, μ_s, b and h.
b) Determine an expression for the slipping force (F_S) in terms of the variables W, μ_s, b and h.
c) Determine an expression for height (h) for which the chest will be on the verge of both tipping and slipping in terms of these same variables?



F_T =	(2 pts)
F_S =	(2 pts)
h =	(1 pt)

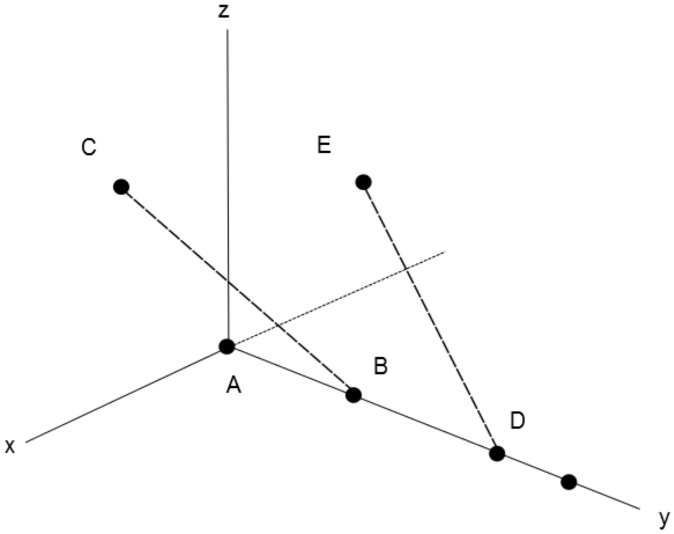
PROBLEM 2. (20 points)

GIVEN: A heavy crate of unknown weight W is suspended from the end of a boom which is supported by two cables. The boom is attached to the wall with a ball and socket joint and has negligible mass.



FIND:

a) On the sketch provided, show a **complete free-body diagram of the boom** (3 pts):



b) Write the **tension in cables BC and DE in vector form (hint: fractions may simplify later math)** (4 pts):

$\overline{T_{BC}} =$	(2 pts)
$\overline{T_{DE}} =$	(2 pts)

c) Find the **magnitude of the tension in each cable in terms of the unknown weight W (hint:** $\sum \bar{\boldsymbol{M}} = \sum \bar{\boldsymbol{r}} \boldsymbol{x} \bar{\boldsymbol{F}}$**)** (8 pts):

$\lvert \overline{\boldsymbol{T}_{\boldsymbol{BC}}} \rvert =$	(4 pts)
$\lvert \overline{\boldsymbol{T}_{\boldsymbol{DE}}} \rvert =$	(4 pts)

e) Cable BC **or** DE **can support a tension of 900 lb at maximum before they fail**. Determine the **maximum weight of the crate** that can be suspended from the end of the boom **such that neither cable will fail** (2 pts):

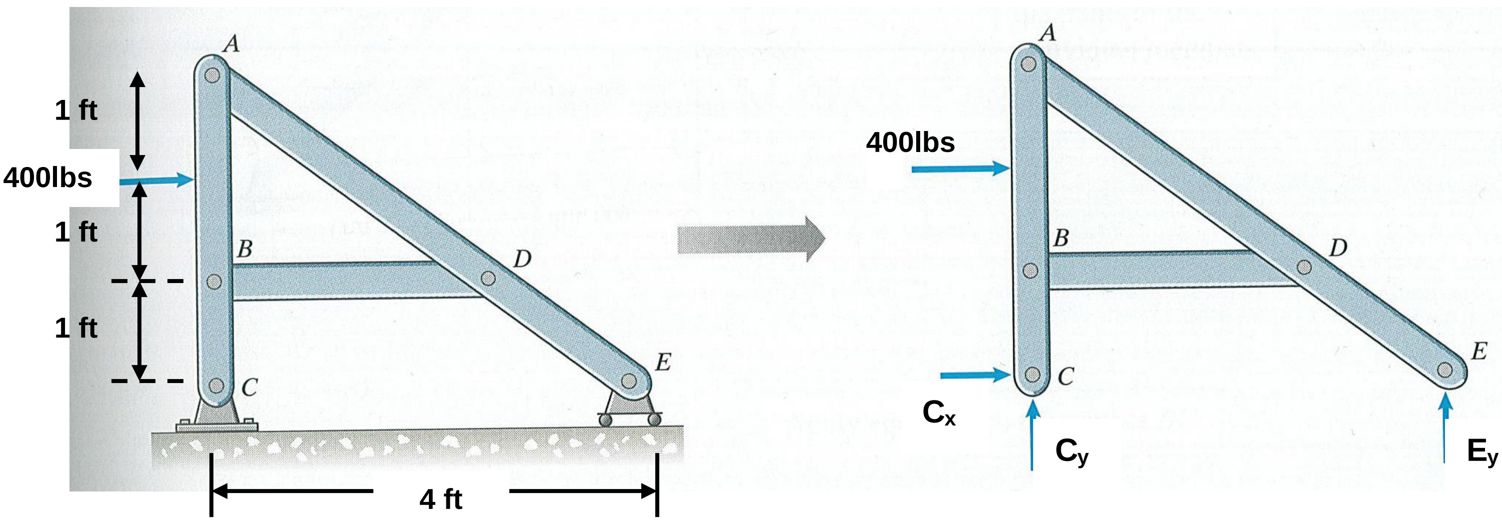
$\boldsymbol{W =}$	(2 pts)

f) Write the **sum of the forces in the component x, y, and z directions in variable form** (**do not solve for the unknown reaction forces**) (3 pts):

$\boldsymbol{\sum F_{Ax} = 0 =}$	(1 pts)
$\boldsymbol{\sum F_{Ay} = 0 =}$	(1 pts)
$\boldsymbol{\sum F_{Az} = 0 =}$	(1 pts)

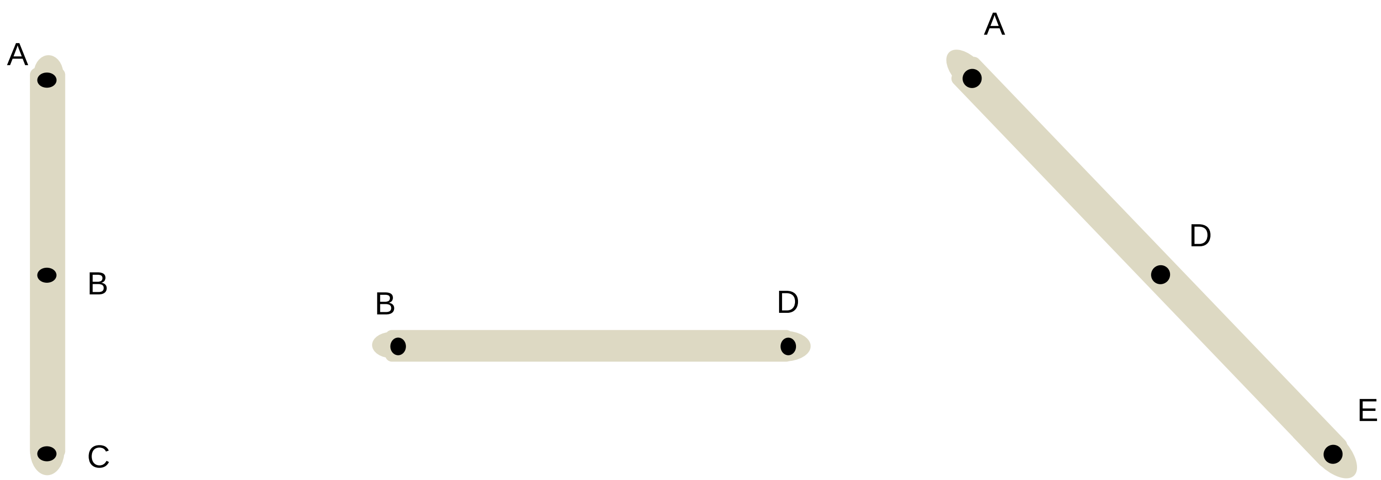
PROBLEM 3. (20 points)

Given: The frame shown is subjected to a 400lb load as shown. Assume the weight of the members is negligible. The frame is held in static equilibrium by a pin support at C (**using a double shear pin**) and a roller support at E. Assume the following properties for the members including the pin at C. The modulus of elasticity (E) is 10 x 10^3 psi and the shear modulus is 4 x 10^3 psi. The cross-sectional area of each member is 2 in^2. The cross-sectional area of the pin at C is 0.5 in^2.



Find:

3a. The overall free-body diagram is provided above. Please complete the individual free-body diagrams on the sketches provided below. (3pts).



Problem 3 Cont.

3B. Determine the reactions at C and E in vector form.

$\bar{C} =$	(2 pts)
$\bar{E} =$	(2 pts)

3C. Determine the average shear stress and shear strain for pin C.

$(\tau_c)_{avg} =$	(3 pts)
$(\gamma_c)_{avg} =$	(2 pts)

3D. Determine the magnitude of the load in member BD and circle whether it's in tension or compression.

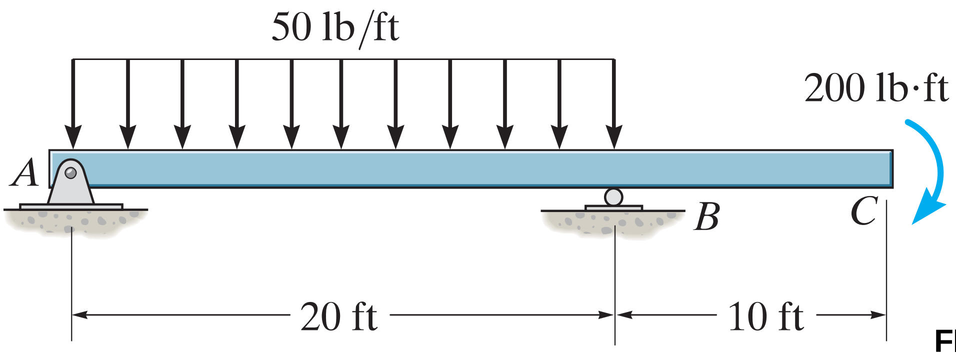
$F_{BD} =$	Tension or Compression (Circle One) (3 pts)

3E. Determine the average axial stress and axial strain in member BD.

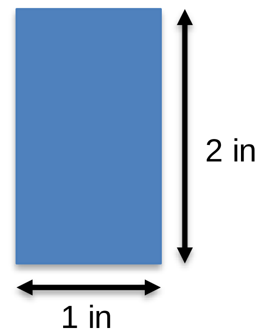
$(\sigma_{BD})_{avg} =$	(3 pts)
$(\varepsilon_x)_{avg} =$	(2 pts)

PROBLEM 4. (20 points)

GIVEN: Consider the beam ABC with the external loads shown in the figure. The support at A is a pin and the support at B is a roller. The cross section of the beam is **rectangular** shown in the figure. The beam is made out of steel. The **tensile fail stress** of steel is $\sigma_{\text{fail}} = 36\text{ksi}$ and its **shear fail stress** is $\tau_{\text{fail}} = 20\text{ksi}$.



Cross section



FIND:

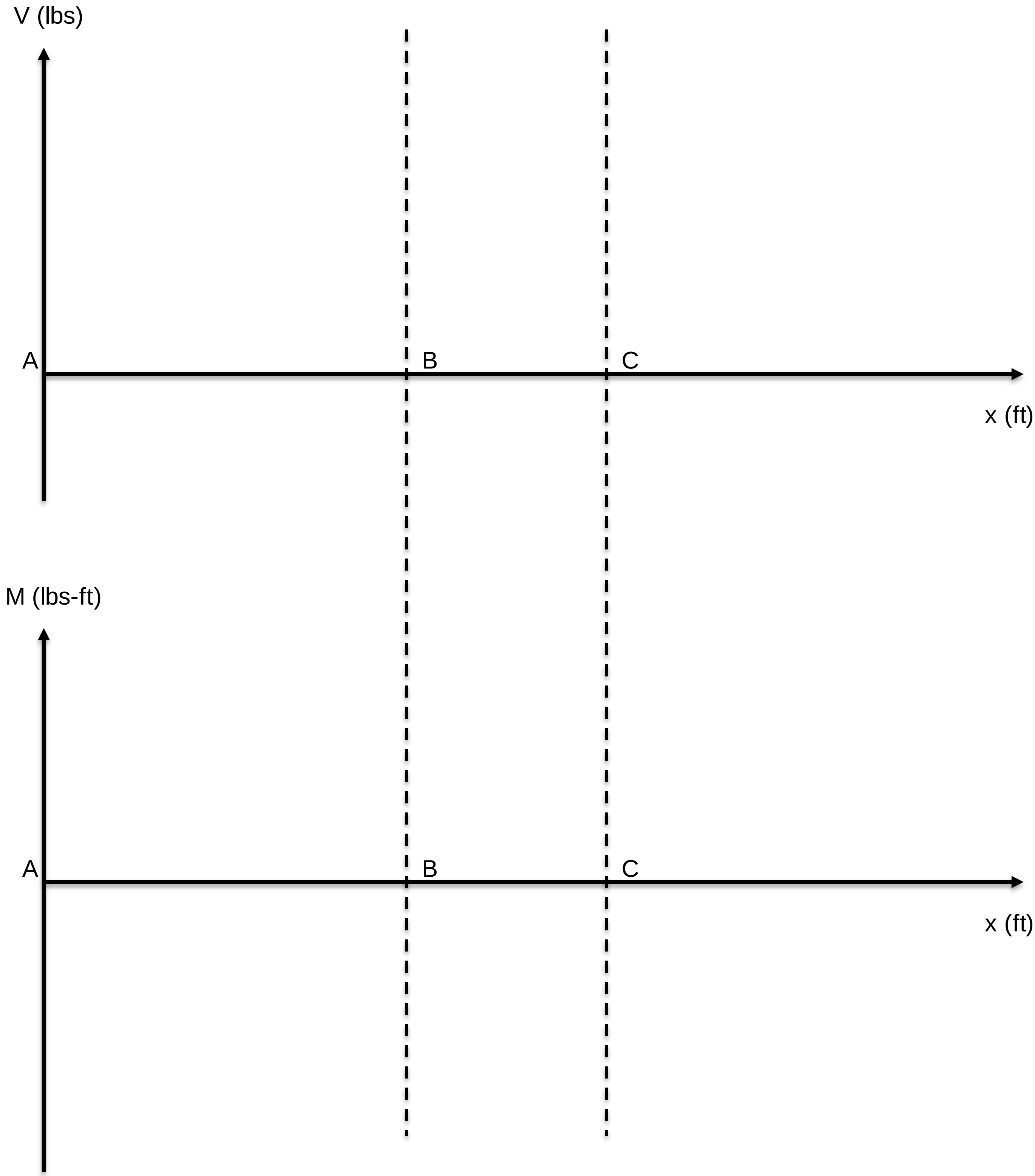
a) Draw the **free body diagram** of the beam ABC and **calculate the reaction forces at the supports** (6 pts).

A_y = ______________________________

A_x = ______________________________ (6 pts)

B_y = ______________________________

b) Draw the **shear force** and **bending moment diagram** of the beam ABC. In order to receive full credit, you must **label** the shear force and bending moment values on the diagram at points A, B, and C, as well as the point(s) at which shear stress crosses zero and the point(s) at which the bending moment is maximum. (8 pts). You may use the graphical method (8 pts).



c) At which point(s) is the beam under **pure bending**? If there are more than one locations, list all of them in order to get full credit. If pure bending occurs over a segment of the beam, then then list it by reporting its x-range using the same axis as the one you used in question b). (2 pts)

Pure bending occurs at: ____________________________________ (2 pts)

d) Cut the beam at the point of pure bending. If in c) you found more than one, then pick the one that has the maximum bending moment. What is the **maximum axial stress** $\sigma_{\max}$ that occurs in this cross section? (2 pts)

The pure bending location exhibiting the maximum bending moment (in ft measured from A) = ________________ (2 pts)

$\sigma_{\max}$ = ____

e) Is the **bottom** part of this pure bending point in **compression** or in **tension** (1 pt)?

Compression or **Tension** (circle one) (1 pt)

f) Will the beam break? If yes, where will it break and why? (1 pt)

Yes or **No** (circle one)

Where and why: (1 pt)

____

____

____

____

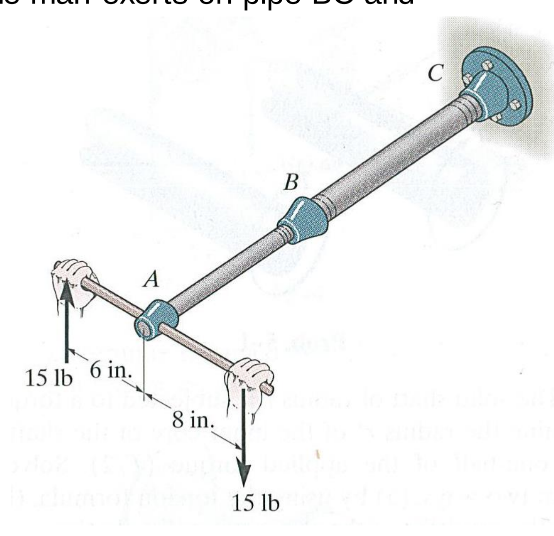
PROBLEM 5. (20 points)

5A. An octagon-shape of 10 inches per side is punched out of of ¼ inch aluminum sheet metal to make "STOP" signs. If the failure stress of the aluminum is 20 ksi, determine the minimum punching force (F) required to punch out the signs. If the maximum capacity of the punch press was 500,000 lbs, determine the maximum shear stress that could be generated for punching an equalateral "YIELD" sign which is 20 inches per side and ¼ inches thick?

F = (3 pts)

$(\tau)_{MAX}$ = (2 pts)

5B. A man applies a torque as shown in the figure. Pipe BC is hollow and has an outer diameter of 2 inches and an inner diameter of 1 inch. Determine the torque the man exerts on pipe BC and determine the torsional stress on the **<u>inner</u>** surface of the pipe.

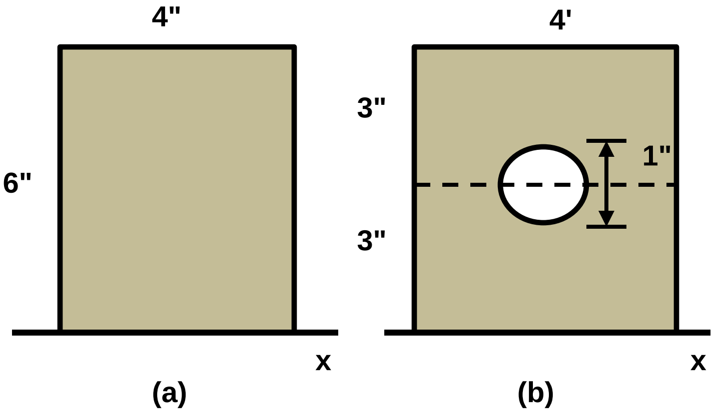


T = (2 pts)

$(\tau)_{\text{inner}}$ = (3 pts)

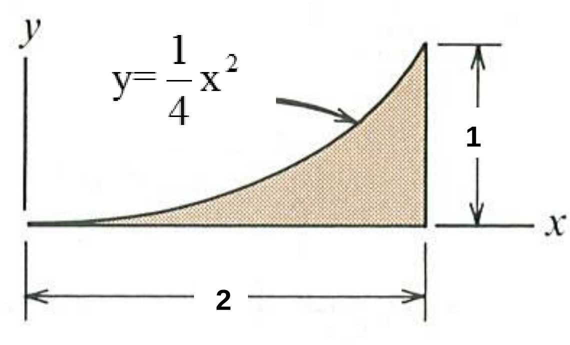
PROBLEM 5. Cont.

5C. Determine the second moment of area of both shapes about the x-axis.



$(I_x)_{\text{Case a}} =$	(2 pts)
$(I_x)_{\text{Case b}} =$	(3 pts)

5D. For the shaded shape, determine the second moment of area (sometimes referred to the moment of inertia) about the x-axis (I_x). Would the I_x about the centroid of the shape be larger, smaller or the same as I_x about the x-axis.



$I_x =$	(3 pts)
$(I_x)_{\text{centroid}} =$ larger smaller same (Circle One)	(2 pts)

ME 270 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

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

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

$$\tau = G\gamma$$

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

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

For a rectangular cross-section,

$$\tau(y) = \frac{6V}{Ah^2}\left(\frac{h^2}{4} - y^2\right)$$

$$\tau_{max} = \frac{3V}{2A}$$

Second Area Moment

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

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

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

$$I_B = I_O + Ad_{OB}{}^2$$

Polar Area Moment

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

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

$$\bar{x} = \frac{\int x_c dA}{\int dA}$$

$$\bar{y} = \frac{\int y_c dA}{\int dA}$$

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

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

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

Centers of Mass

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

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

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

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

ME 270 Final Exam Solutions – Spring 2015

1a. $\bar{F}_A = -400\bar{i} - 300\bar{j}$ N $\qquad \bar{M}_A = -500\bar{k}$ N-m

1b. $W_S = 86.6$ lbs. $\qquad T_{CBA} = 100$ lbs

1c. $\rho_B = pgh = (62.4)d$ $\qquad d = 3$ ft

1d. $F_T = w\dfrac{b}{2h}$ $\qquad F_S = \mu_s N$ $\qquad h = \dfrac{b}{2\mu_s}$

2a. FBD

2b. $$\bar{T}_{BC} = |T_{BC}|\left(\frac{2}{7}\bar{i} - \frac{3}{7}\bar{j} + \frac{6}{7}\bar{k}\right) = 0.286\bar{i} - 0.429\bar{j} + 0.857\bar{k}$$

$$\bar{T}_{DE} = |T_{DE}|\left(-\frac{3}{7}\bar{i} - \frac{6}{7}\bar{j} + \frac{2}{7}\bar{k}\right) = -0.429\bar{i} - 0.857\bar{j} + 0.286\bar{k}$$

2c. $\left|\bar{T}_{BC}\right| = 2.55w = \dfrac{28}{11}w$ lb $\qquad \left|\bar{T}_{DE}\right| = 0.848w = \dfrac{28}{33}w$ lb

2d. W = 353 lb

2e. $$\sum F_x = 0 = \frac{2}{7}T_{BC} - \frac{3}{7}T_{DE} + A_x \qquad \sum F_y = 0 = -\frac{3}{7}T_{BC} - \frac{6}{7}T_{DE} + A_y$$

$$\sum F_z = 0 = \frac{6}{7}T_{BC} + \frac{2}{7}T_{DE} - w + A_z$$

3a. FBDs

3b. $\bar{C} = -400\bar{i} - 200\bar{j}$ lbs $\qquad \bar{E} = 200\bar{j}$ lbs

3c. $(\tau_C)_{avg} = 447$ lb/in^2 $\qquad (\gamma_C)_{avg} = 0.1118$

3d. $F_{BD} = 400$ lbs Tension

3e. $(\sigma_{BD})_{avg} = 200$ lb/in^2 $\qquad (\varepsilon_x)_{avg} = 0.02$ in/in

4a. FBD $\qquad A_y = 490$ lbs. $\qquad A_x = 0$ lbs. $\qquad B_y = 510$ lbs.

4b. Drawing of shear force and bending moment on diagram provided

4c. Pure bending occurs at: 9.8 ft right of A, section

4d. Pure bending location exhibited the max bending moment (in ft measured from A) = 9.8 ft

$\sigma_{max} = 43.218$ ksi

4e. Tension

4f. Yes, $\sigma_{max} > \sigma_{fail}$

5a. $F = 400$ kips $(\tau)_{max} = 33.3$ ksi

5b. $T = 210$ in - lbs $(\tau)_{inner} = 71.3$ psi

5c. $(I_x)_{Case\ a} = 288\ in^4$ $(I_x)_{Case\ b} = 280.9\ in^4$

5d. $I_x = \frac{2}{21}\ units^4$ $(I_x)_{centroid}$ = smaller