ME 270 – Spring 2017 Final Exam **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: ______________________________________

Instructor's Name and Section: (Circle Your Section)

Sections: J Jones 9:30-10:20AM A Buganza 1:30-2:20PM B Li 3:30-4:20PM
J Jones Distance Learning

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.

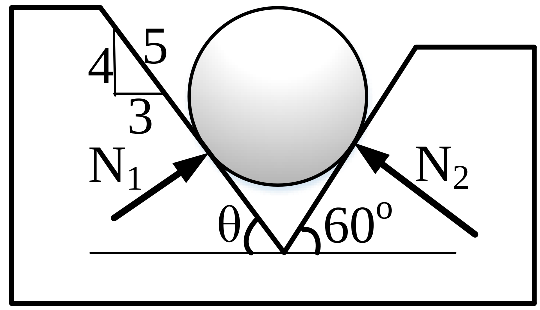
- The only authorized exam calculator is the TI-30IIS
- The allowable exam time for Final Exam is 120 minutes.
- The coordinate system must be clearly identified.
- Where appropriate, free body diagrams must be drawn. These should be drawn separately from the given figures.
- Units must be clearly stated 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.**

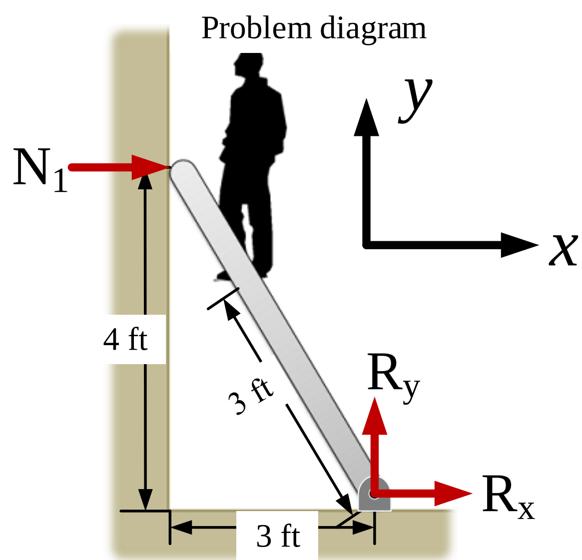
PROBLEM 1 (20 points)

1A. A 500 lbs sphere is held in place within this notch shown. Determine the normal forces $\mathbf{N_1}$ and $\mathbf{N_2}$ from the two contact surfaces.



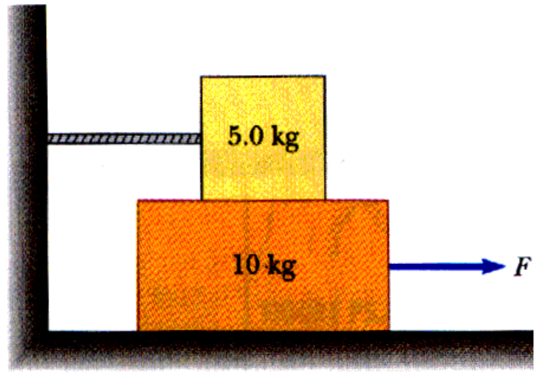
$\boldsymbol{N_1}$ = ____________________ lbs		(2 pts)
$\boldsymbol{N_2}$ = ____________________ lbs		(2 pts)

1B. A person with 200 lbs weight is standing on a ladder as shown. The ladder is held in static equilibrium and supported by the wall and a pin support on the bottom. Suppose the wall is friction less and the weight of the ladder is negligible. Determine the normal forces N_1 and reaction forces Rx and Ry of the pin support.



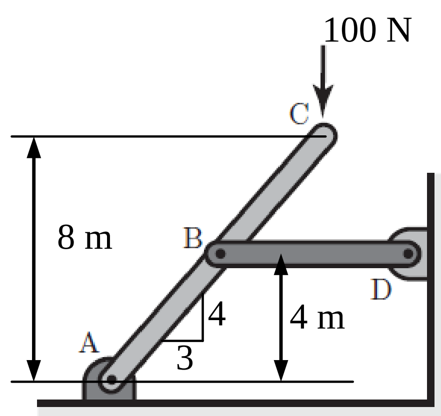
$\boldsymbol{N_1}$ = __________________ lbs		(2 pts)
$\boldsymbol{R_x}$ = __________________ lbs		(2 pts)
$\boldsymbol{R_y}$ = __________________ lbs		(2 pts)

1C. Two blocks are stacked as shown. A short string is attached between the upper block and the wall. Given that μ = 0.2 for all contact surfaces, find the required force **F** to pull the block out and the magnitude of tension **T** carried in the string.



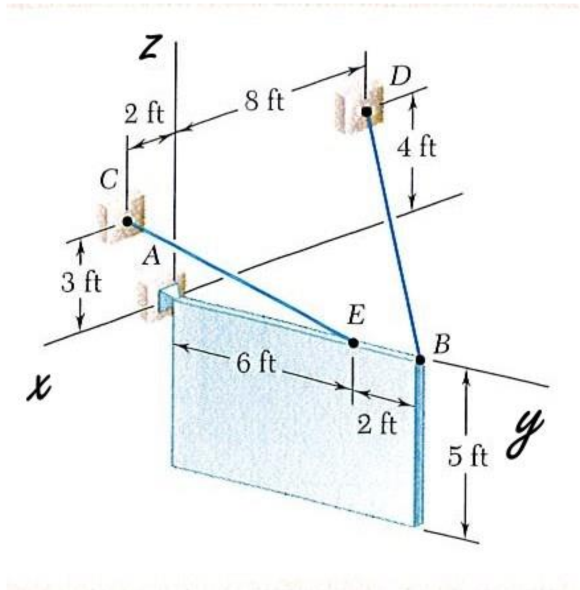
F = _______________ **N**		(3 pts)
T = _______________ **N**		(2 pts)

1D. An external load of 100 N is applied to the frame ABCD shown. Both A and D are pin supports. Determine the magnitude of force acting on member BD. (5 pts)



F_{BD}________________ N	**Tension**	**Compression**	**(circle one)**	(5 pts)

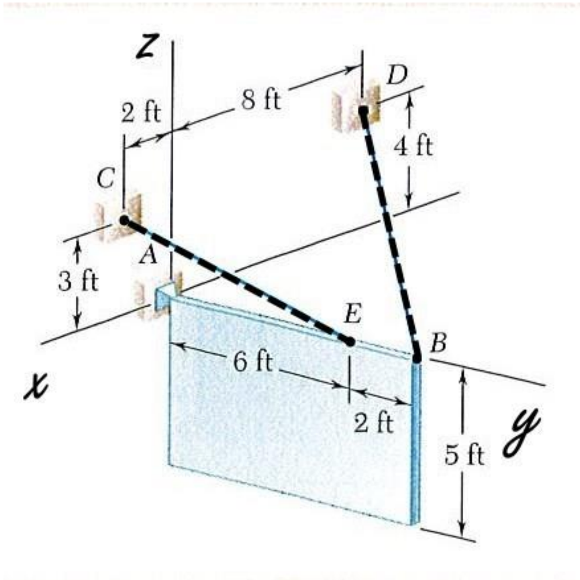
PROBLEM 2. (20 points)



GIVEN: A 5 ft x 8 ft sign of uniform density weights 240 lbs. The sign is held in Static equilibrium by a ball-an-socket support at A and cables EC and BD.

FIND:

a) On the sketch provided, complete the free body diagram of the sign. (2 pts)



b) Write vector expressions for the forces in cables EC and BD in terms of their unknown magnitudes and their known unit vectors. (4 pts)

$\bar{T}_{EC}$ = (2pts)

$\bar{T}_{BD}$ = (2pts)

c) Determine the magnitudes of the tensions in cables EC and BD. (10 pts)

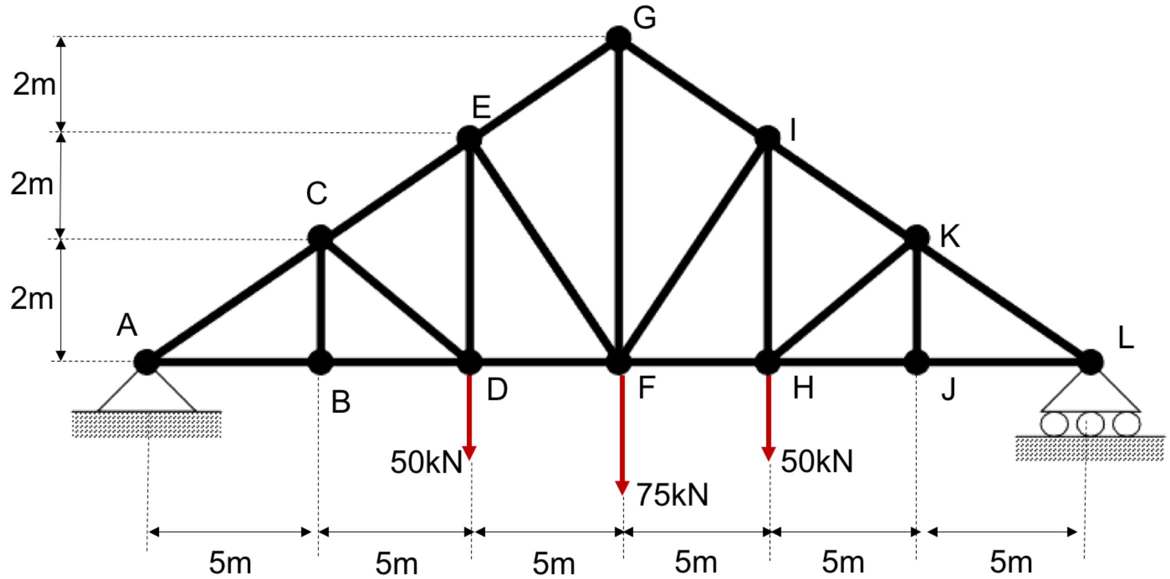
$\left|\bar{T}_{EC}\right| =$	(5 pts)
$\left|\bar{T}_{BD}\right| =$	(5 pts)

d) Determine the magnitude of the reaction at the ball and socket support in the Z direction. (4 pts)

$A_z =$	(4 pts)

PROBLEM 3. (20 points)

Consider the truss shown in the figure. The truss is supported by a pin joint at A and a roller support at L and is in static equilibrium.



FIND:

a) Identify all zero force members: ________________________________ **(2 pts)**

b) Determine the reactions at A and L, write your answer in vector form

$\boldsymbol{F_A} =$	**(2pts)**
$\boldsymbol{F_L} =$	**(2pts)**

c) Solve for the load in member EG and whether its in tension or compression.

$\|F_{EG}\| =$	**(3pts)**	**Tension or Compression:**	**(1pt)**

d) Solve for the magnitude of the force in member FG and determine whether it is in tension or compression

$\|F_{FG}\| =$	**(3pts)**	**Tension or Compression:**	**(1pt)**

e) Member FG is made out of steel which fails at $\sigma_{fail} = 250$ MPa. Determine the minimum cross-sectional area of member FG if we design it considering a factor of safety of 2.

$\boldsymbol{Area\ =}$ **(4pts)**

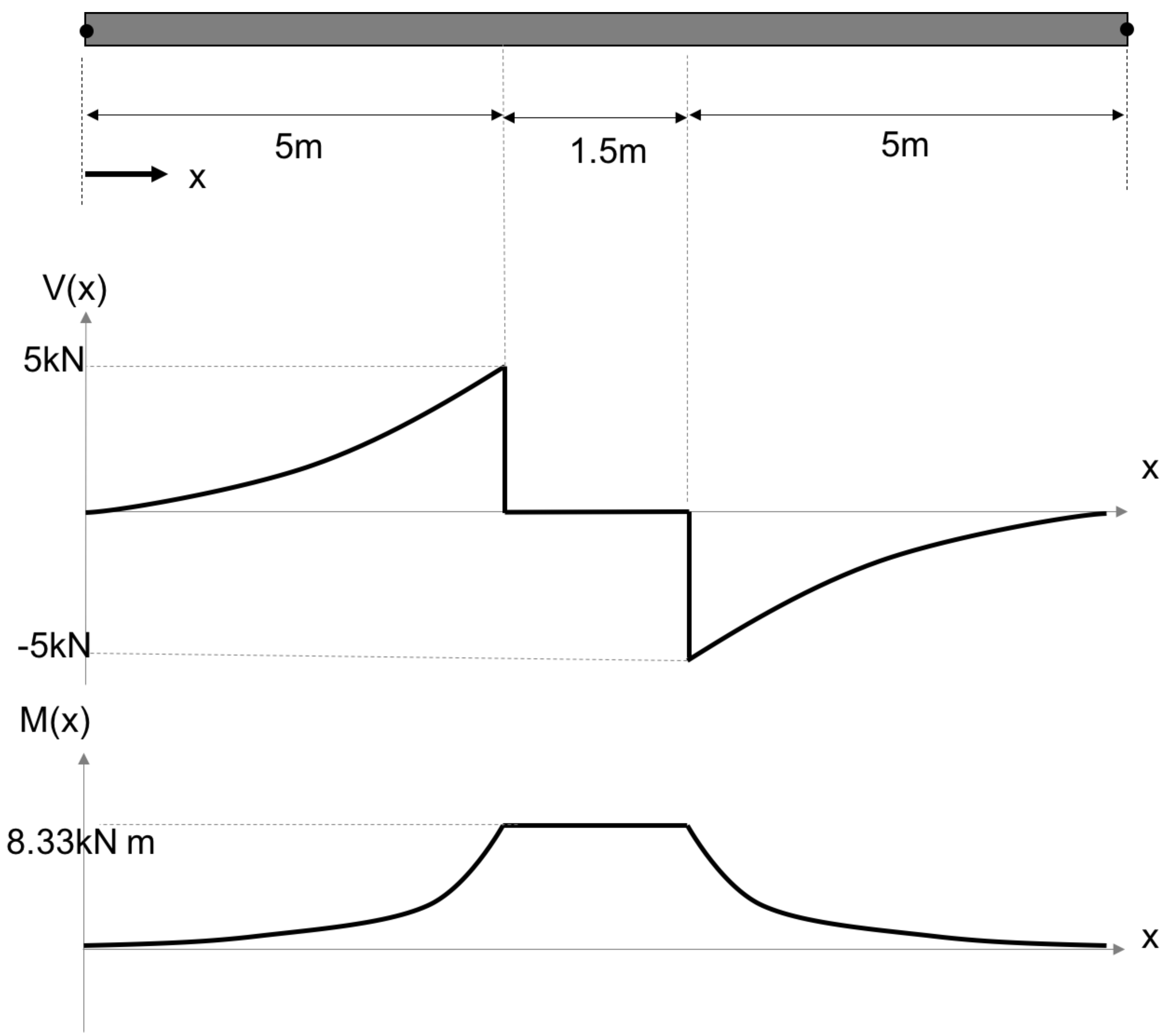
f) Define the following:

Statically determinate truss **(1 pt)**:

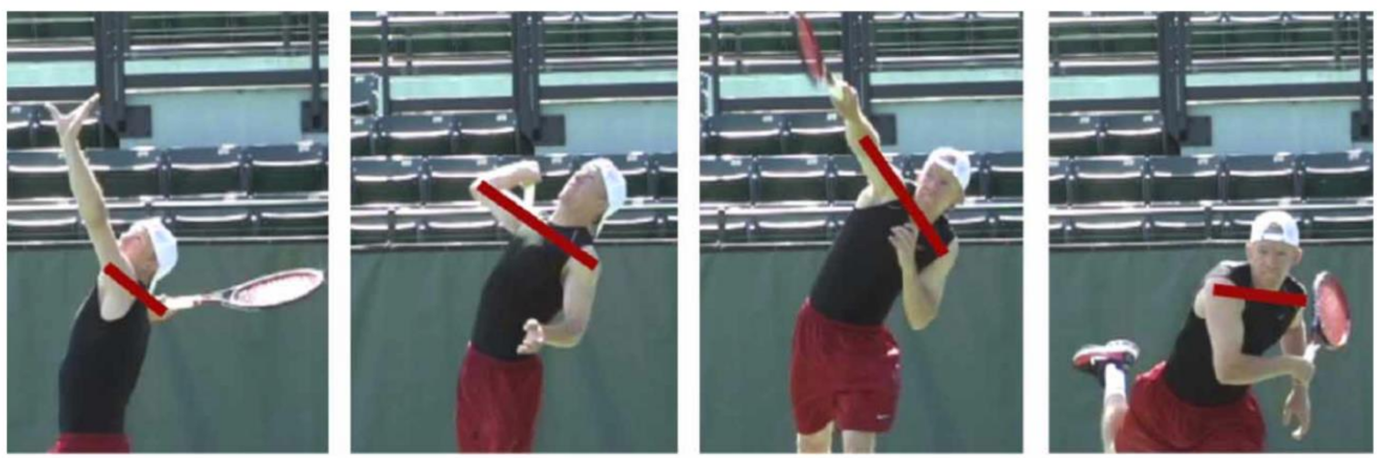
Statically indeterminate truss **(1 pt)**:

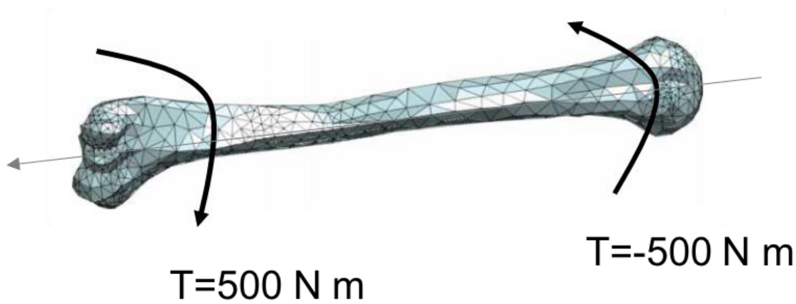
PROBLEM 4. (20 points)

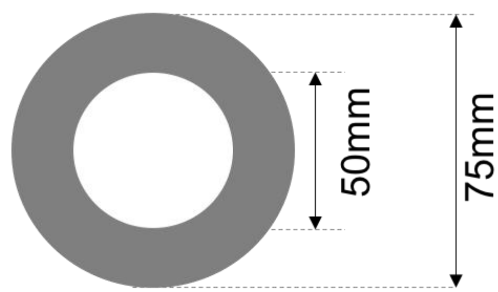
4A Given the shear force and bending moment diagram draw the corresponding load on the beam **(5 pts)**



4B When a tennis player serves it creates a torsional moment on the humerus as shown in the figure. Assuming that the cross section of the humerus is tubular with the dimensions depicted in the figure, determine the shear stresses at the inner and outer surfaces of the bone

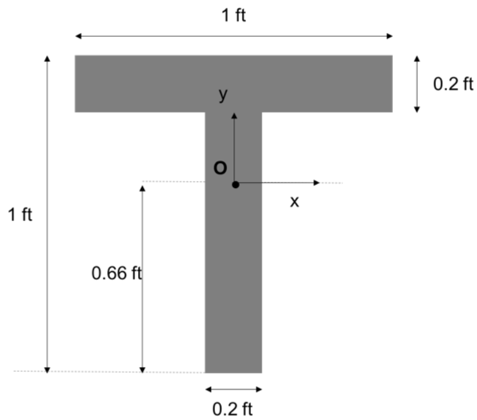






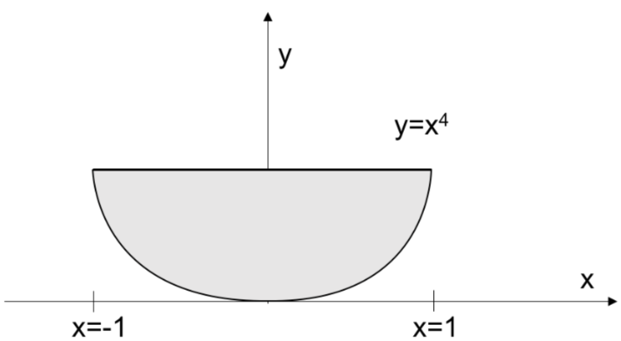
$\boldsymbol{\tau_{inner}} =$	**(3pts)**
$\boldsymbol{\tau_{outer}} =$	**(2pts)**

4C Determine the second area moment Ix_O for the T cross section. The value of Iy_0 as compared to Ix_0 should be larger/equal/smaller (no calculations should be necessary).



I_{xo} =					**(4pts)**
I_{yo}	**is**	**larger**	**equal**	**smaller**	**(1pt)**

4D Determine the second area moment I_x for the given parabolic shape with respect to the x axis. Is the second area moment with respect to the centroid I_o greater or less than I_x?



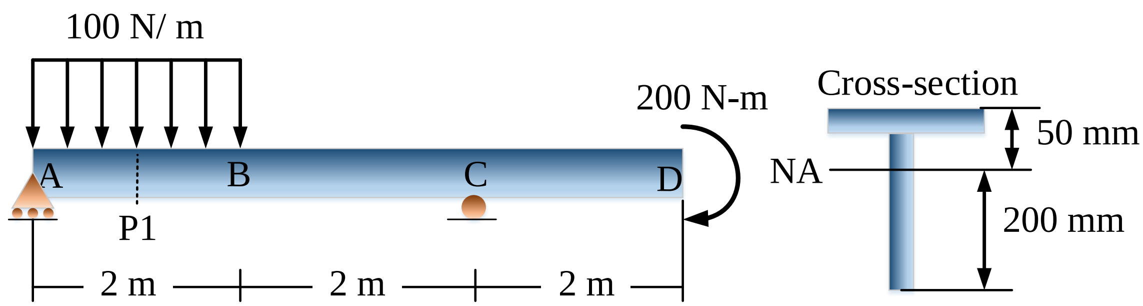
I_x =			**(2pts)**
$I_o > I_x$	**true**	**false**	**(3pts)**

PROBLEM 5. (20 points)

Beam ABCD is loaded as shown and is held in static equilibrium by a roller support at A and a roller support at C. The center point of segments AB is labeled as P1. The beam cross-section is "T-shaped" with a second area moment of inertia $I_x = 10 \times 10^{-6}$ m^4. (NA refers to the neutral axis)

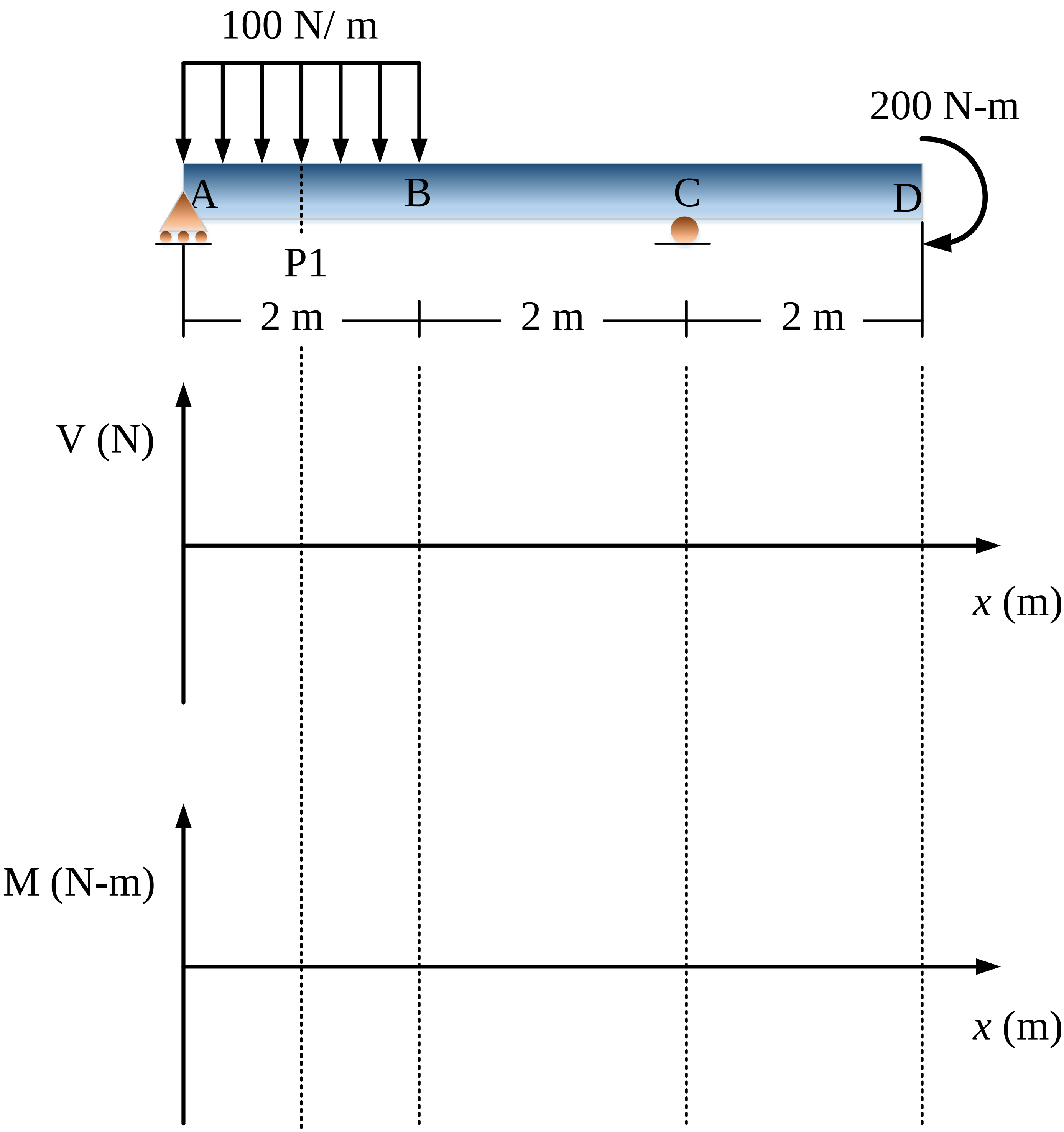
FIND:

a) Sketch a free-body diagram of the beam and determine the reactions at A and C in vector form. (Note: please use a single equivalent force to represent the distributed loads). (6 pts)



$\overline{A}$ = ______________________ N	(2 pts)
$\overline{C}$ = ______________________ N	(2 pts)

b) On the axes provided, sketch the shear-force and bending moment diagram of the beam. (6 pts)



c) In which segment(s) or point(s) along the beam does pure bending occur (2 pts)?

Segments:	**AB**	**BC**	**CD**	**None**		**(circle all that apply)**	(1 pts)
Points:	**A**	**P1**	**B**	**C**	**D**	**(circle all that apply)**	(1 pts)

d) In the segment(s) or point(s) of the beam where pure bending exists, determine the magnitudes of maximum tensile bending stress $(\sigma_{max})_T$ and maximum compressive bending stress $(\sigma_{max})_C$. (6 points)

$(\sigma_{max})_T$ = ____________________	**MPa**	**Top**	**Bottom**	**(circle all that apply)**	(3 pts)
$(\sigma_{max})_C$ = ____________________	**MPa**	**Top**	**Bottom**	**(circle all that apply)**	(3 pts)

Solutions

1A. $N_1 = 471\ lbs$ $N_2 = 435\ lbs$

1B. $N_1 = 90\ lbs$ $R_x = -90\ lbs$ $R_y = 200\ lbs$

1C. $F = 39.2\ N$ $T = 9.8\ N$

1D. $F_{BD} = -150N\ (Compression)$

2A. **Free body diagram**

2B. $T_{EC} = T_{EC}\ (0.285\bar{\imath} - 0.857\bar{\jmath} + 0.428\bar{k})$

$T_{BD} = T_{BD}\ (-0.667\bar{\imath} - 0.667\bar{\jmath} + 0.333\bar{k})$

2C. $\left|\bar{T}_{EC}\right|$ **= 280 lbs.** $\left|\bar{T}_{BD}\right|$ **= 90.0 lbs**

2D. $A_Z = 90.1\ lbs$

3A. **BC, CD, HK, KJ**

3B. $F_A = 87.5\ \bar{\jmath}\ kN$ $F_L = 87.5\ \bar{\jmath}\ kN$

3C. $|F_{EG}|$ **= 190.72 kN Compression**

3D. $|F_{FG}|$ **= 141.66 kN Tension**

3E. $Area = 0.00113m^2$

3F. **Definitions**

4A. **Shear-Force and Bending-Moment Diagrams**

4B. $\tau_{inner} = 5.01\ MPa$ $\tau_{outer} = 7.52\ MPa$

4C. $I_{xo} = 0.0315ft^4$ $I_{yo}\ is\ smaller$

4D. $I_x = 0.615$ $I_o > I_x\quad false$

5A. $A = 100\ \bar{\jmath}\ N$ $C = 100\ \bar{\jmath}\ N$

5B. **Shear-Force and Bending-Moment Diagrams**

5C. **Segments: CD** **Points: P1**

5D. $\langle\sigma_{max}\rangle\ T = 1\ MPa$ **Top and Bottom** $\langle\sigma_{max}\rangle\ C = 4\ MPa$ **Bottom Only**

Spring 2017 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

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

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

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

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

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

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

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

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

Centers of Mass

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

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