Name: ________________________________ **Instructor:** **Rao** **Koslowski**
(Print) (Last) (First) (Circle one)

ME 323 FINAL EXAM
Spring 2008
7:00 PM – 9:00 PM

Instructions

1. Work each problem in the space provided.
2. Confine your work to the front side of the pages only.
3. Additional paper will be provided upon request.
4. To obtain maximum credit, you must present your solutions clearly. Accordingly:
    a. Identify coordinate systems
    b. Sketch free body diagrams
    c. State units explicitly
    d. Clarify your approach to the problem, including assumptions
    e. Clearly mark final answers with boxes
5. If your solution cannot be followed, it will be assumed that it is in error.

Prob. 1 ______________________

Prob. 2 ______________________

Prob. 3 ______________________

Prob. 4 ______________________

Total ______________________

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Some useful formulas

$$\varepsilon = \frac{\Delta L}{L} = \frac{L^* - L}{L}$$

$$\varepsilon_x = \frac{1}{E}\left[\sigma_x - \nu\left(\sigma_y + \sigma_z\right)\right] + \alpha\Delta T$$

$$\varepsilon_y = \frac{1}{E}\left[\sigma_y - \nu\left(\sigma_x + \sigma_z\right)\right] + \alpha\Delta T$$

$$\varepsilon_z = \frac{1}{E}\left[\sigma_z - \nu\left(\sigma_x + \sigma_y\right)\right] + \alpha\Delta T$$

$$\gamma_{xy} = \frac{1}{G}\tau_{xy} \quad \gamma_{xz} = \frac{1}{G}\tau_{xz} \quad \gamma_{yz} = \frac{1}{G}\tau_{yz}$$

$$FS = \frac{Failure\ Stress}{Allowable\ Stress}, \frac{Yield\ Strength}{State\ of\ Stress}$$

$$e = \frac{FL}{EA} + L\alpha\Delta T \qquad e = u\cos(\theta) + v\sin(\theta)$$

$$\tau = \frac{Tr}{I_p} \qquad \phi = \frac{TL}{GI_p}$$

$$I_p = \frac{\pi d^4}{32} \quad (solid\ circular\ cross\ section)$$

$$I_p = \frac{\pi(d_o^4 - d_i^4)}{32} \quad (hollow\ circ.\ cross\ sect.)$$

$$\sigma(x,y) = \frac{-E(x)y}{\rho(x)} = \frac{-M(x)y}{I_{zz}}$$

$$\tau = \frac{VQ}{I_{zz}t} \qquad Q(y) = \int_{A'} \eta\, dA = A'\bar{y}'$$

$$I_{zz} = \frac{bh^3}{12}\ (rectangle) \qquad I_{zz} = \pi\frac{d^4}{64}\ (circle)$$

$$EIv'' = M$$

$$(EIv'')' = V$$

$$(EIv'')'' = p$$

$$\langle x-a\rangle^n = \begin{cases} 0 & for\ x < a \\ (x-a)^n & for\ x \ge a \end{cases} \quad n = 0,1,2,3...$$

$$\int \langle x-a\rangle^n dx = \begin{cases} \langle x-a\rangle^{n+1} & for\ n \le 0 \\ \dfrac{1}{n+1}\langle x-a\rangle^{n+1} & for\ n \ge 0 \end{cases}$$

$$\sigma_n = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau_{nt} = -\left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\theta + \tau_{xy}\cos 2\theta$$

$$\sigma_{avg} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \qquad R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_{1,2} = \sigma_{avg} \pm R \qquad \tau_{s1,s2} = \pm R = \pm\tau_{max}$$

$$\sigma_{s1,s2} = \sigma_{avg}$$

$$\tan 2\theta_p = \frac{\tau_{xy}}{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)} \qquad \tan 2\theta_s = \frac{-\left(\dfrac{\sigma_x - \sigma_y}{2}\right)}{\tau_{xy}}$$

$$\sin 2\theta_{p1} = \frac{\tau_{xy}}{R} \qquad \cos 2\theta_{p1} = \frac{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)}{R}$$

$$\sin 2\theta_{p2} = \frac{-\tau_{xy}}{R} \qquad \cos 2\theta_{p2} = \frac{-\left(\dfrac{\sigma_x - \sigma_y}{2}\right)}{R}$$

$$\sin 2\theta_{s1} = \frac{-\left(\dfrac{\sigma_x - \sigma_y}{2}\right)}{R} \qquad \cos 2\theta_{s1} = \frac{\tau_{xy}}{R}$$

$$\sin 2\theta_{s2} = \frac{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)}{R} \qquad \cos 2\theta_{s2} = \frac{-\tau_{xy}}{R}$$

$$\sigma_a = \frac{pr}{2t} \qquad \sigma_h = \frac{pr}{t} \qquad \sigma_{sphere} = \frac{pr}{2t}$$

$$\Delta_i = \frac{\partial U_{Total}}{\partial P_i} \qquad \theta_i = \frac{\partial U_{Total}}{\partial M_i} \qquad i = 1,2,....$$

$$U_{Total} = \int_0^L \frac{F^2}{2AE}dx + \int_0^L \frac{T^2}{2GI_P}dx + \int_0^L \frac{M^2}{2EI}dx + \int_0^L \frac{f_s V^2}{2GA}dx$$

$$\sigma_M = \frac{\sqrt{2}}{2}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2\right]^{1/2}$$

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} \qquad \sigma_{cr} = \frac{\pi^2 E}{(L_e/r)^2}$$

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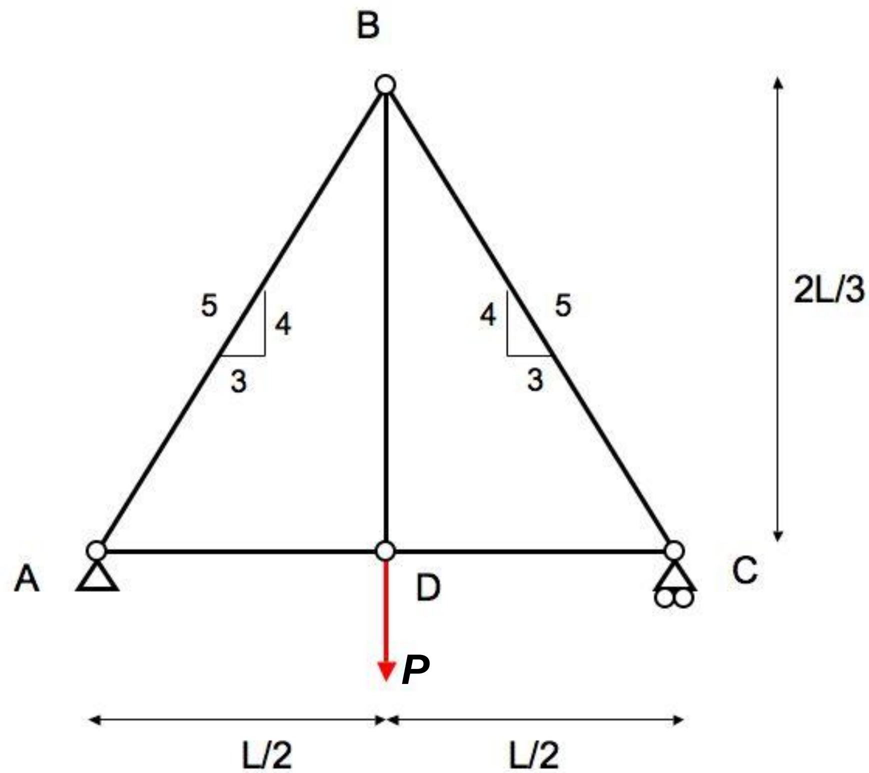
PROBLEM #1 ***(20 points)***

The pictured planar truss ***ABCD*** with height ***h=2L/3*** and span length ***L*** supports a downward vertical load ***P*** at joint ***D***. If each member has axial rigidity ***AE***, determine the following:

a) The support reactions at ***A*** and ***C***

b) The internal resultant forces in all truss elements

b) The vertical displacement of the joint ***D*** using energy methods



$$L_{AB} = L_{BC} = \frac{5}{6}L$$

$$L_{AD} = L_{CD} = \frac{1}{2}L$$

$$L_{BD} = \frac{2}{3}L$$

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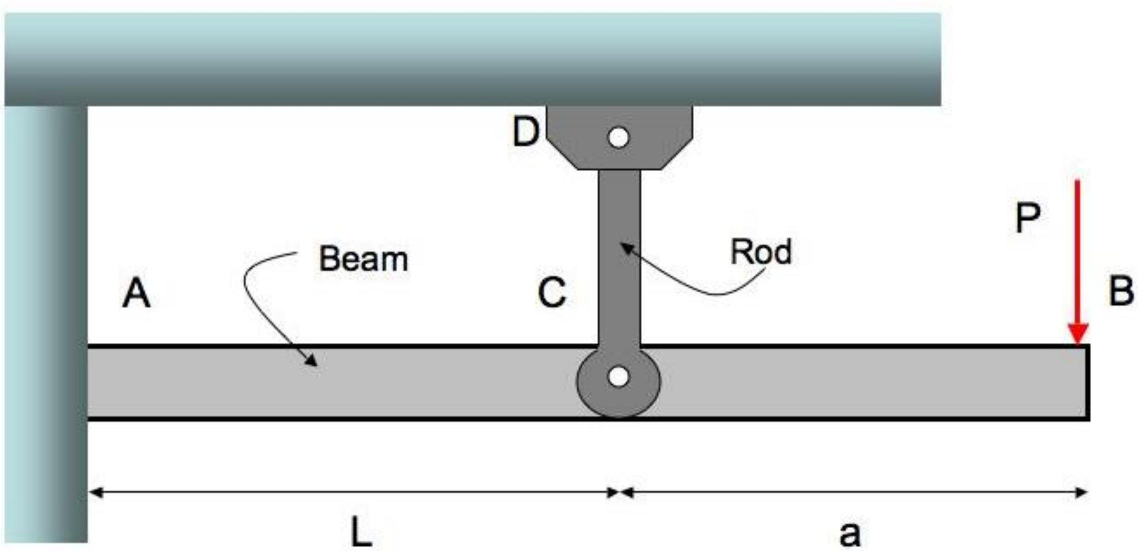
PROBLEM #2 ***(30 points)***

The pictured cantilever beam ***AB*** is clamped at end ***A***, free at end ***B***, and is reinforced at location ***C*** by rod ***CD*** (which is pinned at both ends). When load ***P*** is applied at point ***B*** the beam deflects downward at ***C*** thus developing a reactive tensile force ***T*** in rod ***CD***. Relevant properties of the beam and rod are given in the table below.

	Beam	Rod
Young modulus	E	E_1
Moment of inertia	I	I_1
Area	A	A_1
Length	L+a	L_1
		$k = A_1 E_1 / L_1$



a) Plot the anticipated deflection curve in the space provided in the next page

b) Draw a free body diagram of the beam in the space provided in the next page

c) Write an expression for the force ***T*** as a function of ***P***, ***k***, ***L***, ***a***, ***E***, and ***I***

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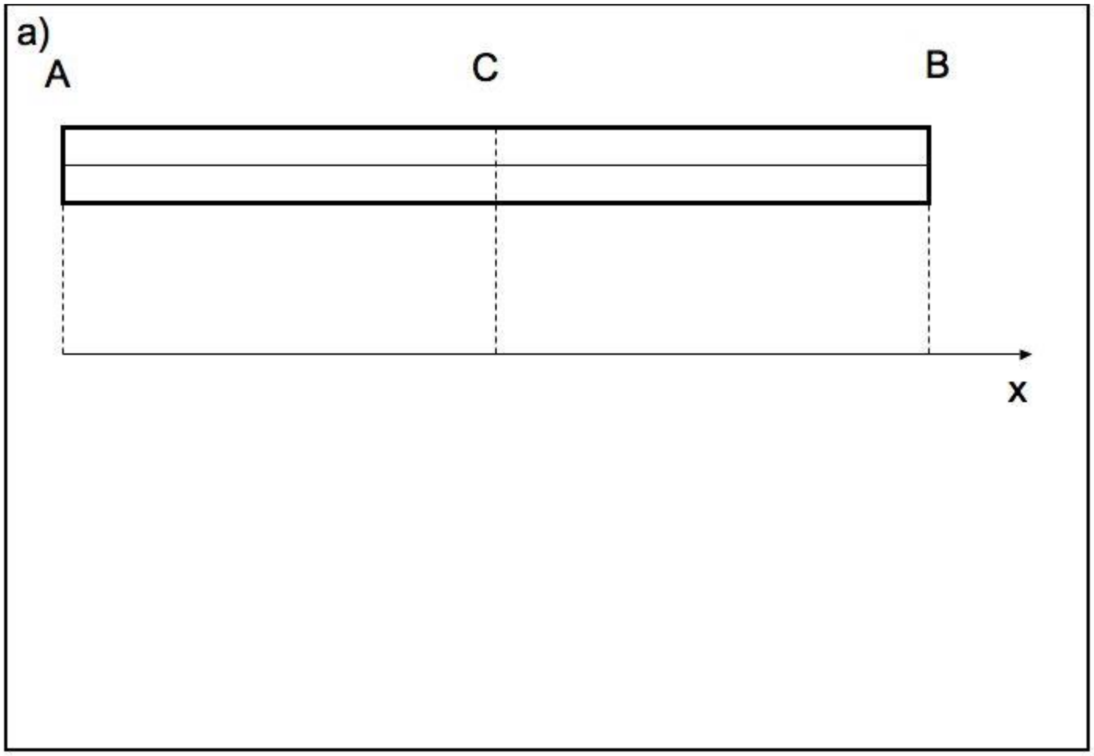

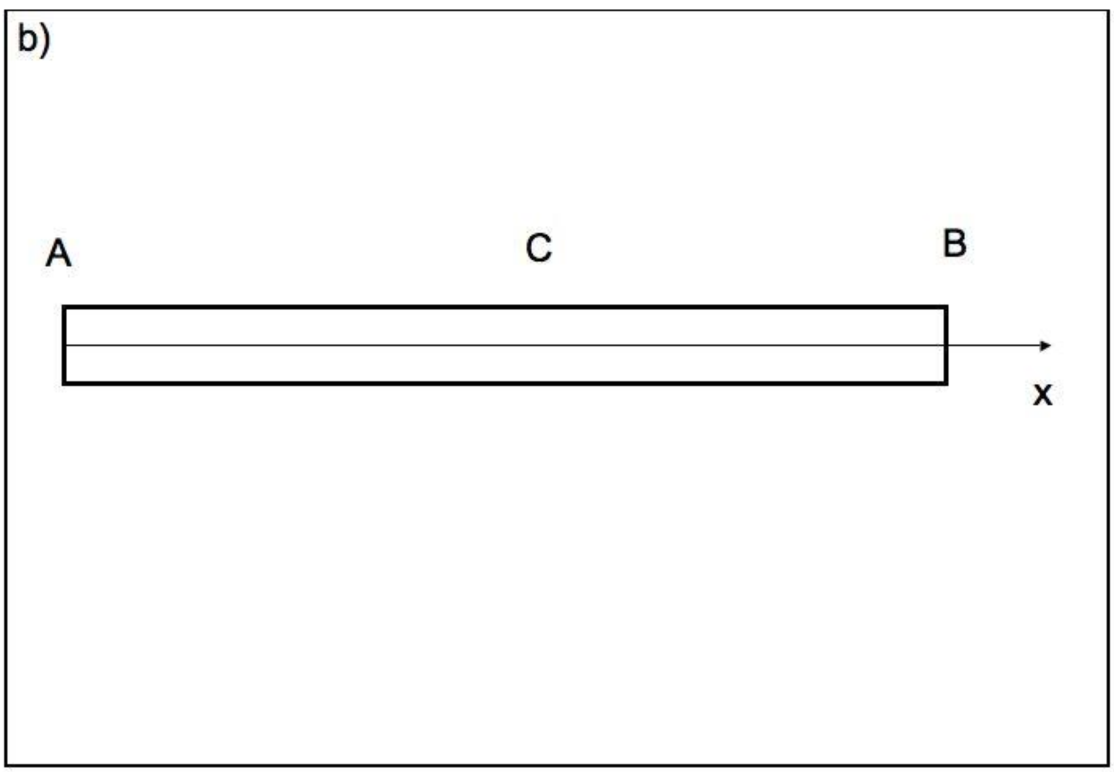

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PROBLEM #3 ***(30 points)***

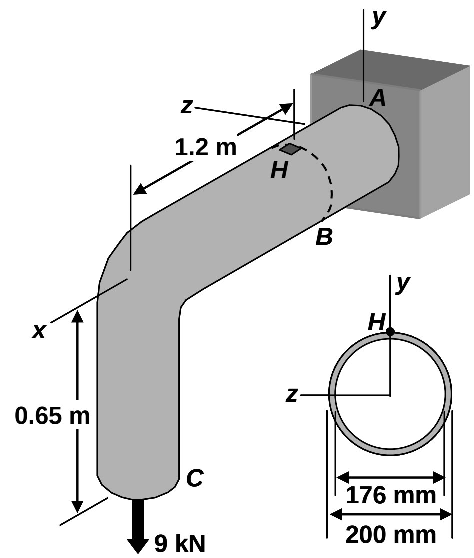
The pictured section of a gas pipeline is rigidly fixed at ***A*** and is subjected to a ***9 kN*** load in the ***–y*** direction at ***C***. The outer diameter of the pipe is ***200 mm*** and the inner diameter is ***176 mm***. If the internal pressurization in the pipeline is ***1500 kPa***, determine the following at point ***H*** (i.e. top of the cross section at point ***B***):

A) The stress state

Provide all non-zero stress components for a material element in the ***xyz*** *coordinate system shown in the figure*

B) The absolute maximum shear stress

C) Whether the pipe will fail according to Von Mises Criterion, assuming the pipe is made of steel (yield strength = ***250 MPa***).



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PROBLEM #4 ***(20 points)***

The rigid bar ***ABC*** shown below is attached to a rigid base by a pin joint at ***C***. Bar ***BD*** is a pin-jointed rectangular cross section compression member that connects ***ABC*** and the base. If Member ***BD*** is made of aluminum (elastic modulus = $\boldsymbol{10 \times 10^3}$ ***ksi***; yield strength = ***40 ksi***) determine:

A) The maximum load that can be applied at point ***A*** without causing buckling of ***BD***

B) Whether Euler buckling analysis is valid for Member ***BD***