**Name (Print)**________________________________________________

**(Last) (First)**

# ME 323 - Mechanics of Materials
# Exam # 2
## Date: November 6, 2019 Time: 8:00 – 10:00 PM

**Instructions:**

**Circle your instructor's name and your class meeting time**.

| Gonzalez | Kokini | Zhao | Pribe |
|---|---|---|---|
| 11:30-12:20PM | 12:30-1:20PM | 2:30-3:20PM | 4:30-5:20PM |

The only authorized exam calculator is the TI-30XIIS or the TI-30Xa.

Begin each problem in the space provided on the examination sheets.

Work on **ONE SIDE** of each sheet only, with only one problem on a sheet.

Please remember that for you to obtain maximum credit for a problem, you must present your solution clearly. Accordingly,

- coordinate systems must be clearly identified,
- free body diagrams must be shown,
- units must be stated,
- write down clarifying remarks,
- state your assumptions, etc.

If your solution cannot be followed, **it will be assumed that it is in error**.

When handing in the test, make sure that ALL SHEETS are in the correct sequential order.

**Please review and sign the following statement:**

Purdue Honor Pledge – "As a Boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together – We are Purdue."

**Signature:** ___________________________________

**ME 323 Examination # 2** **Name ____________________________________**
**(Print) (Last) (First)**

**PROBLEM #1 (25 Points):**

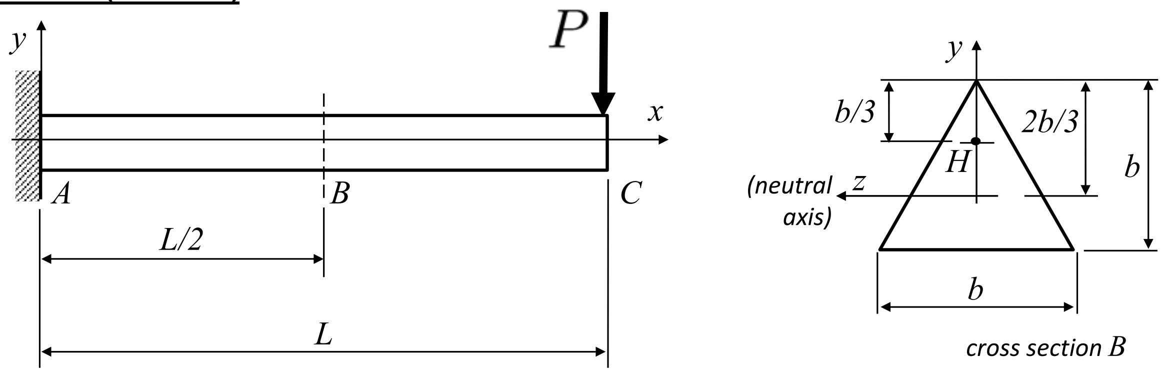



**Figure 1**

For the cantilever beam shown in the above figure:

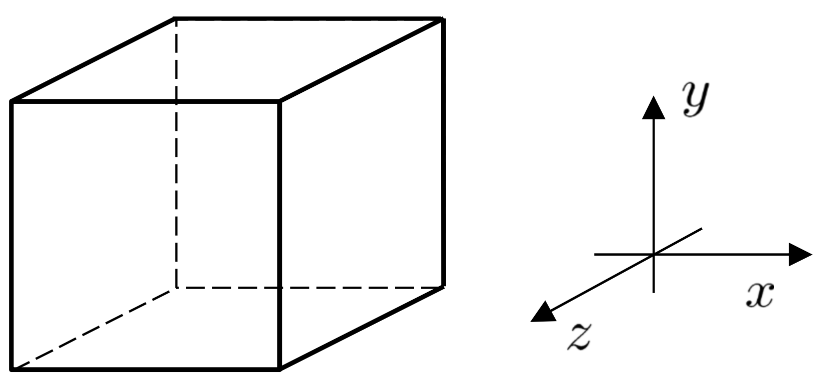
a) Determine the reactions at the wall.

b) Determine the normal stress at point *H* of cross section *B*.

c) Determine the shear stress at point *H* of cross section *B*.

d) Show the state of stress at point *H* on the differential stress element shown below.

Note: $P = 25$ N, $L = 1$ m, $b = 0.03$ m, $I_{zz} = b^4/36$



**Name** ________________________________
**(Print)** **(Last)** **(First)**

## PROBLEM #2 (25 points)

The beam BCD is fixed to the wall at B and supported by a roller at C. An external moment $\boldsymbol{M_0}$ is applied at C. The beam has Young's modulus $\boldsymbol{E}$ and second moment of area $\boldsymbol{I}$.

a) Draw a free-body diagram of the entire beam, and write down the equilibrium equations.

b) Use the second-order (or fourth-order) integration method to find the slope $v'(x)$ and deflection $v(x)$ of each segment of the beam. These can be left in terms of the unknown support reactions.

c) Write down the relevant boundary conditions and continuity conditions for the beam.

d) Use the boundary/continuity conditions to determine the reactions at B and C in terms of $\boldsymbol{M_0}$ and $\boldsymbol{L}$.

e) Determine the deflection at the free end D. Sketch the deflection curve over the length of the beam. The sketch does not need to be exact; show enough detail to indicate the boundary conditions.

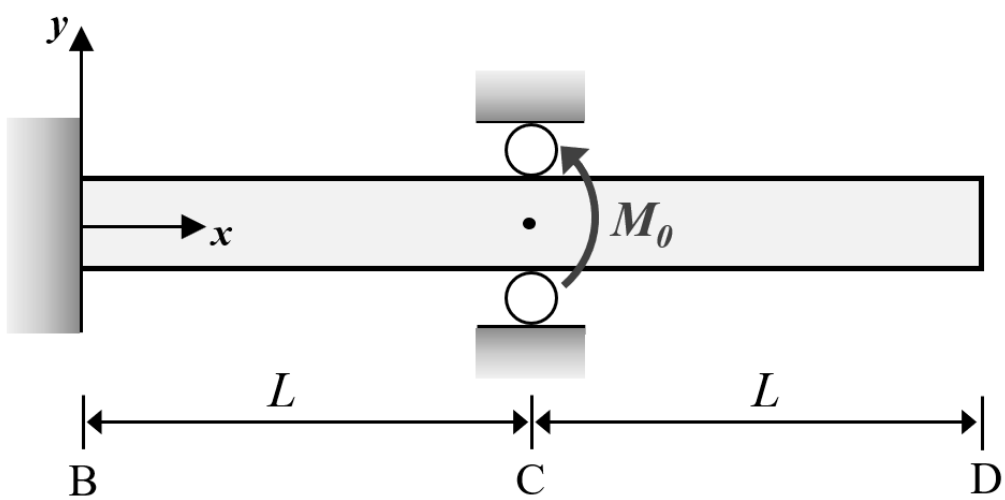



**Figure 2**

**Problem 7.4 (10 points):** The beam AD is fixed to a rigid wall at A and is supported by props at B and C. In spans AB and BC the flexural rigidity is *EI*, but in span CD the flexural rigidity is *2EI*. The beam supports a linearly distributed load over span BC.

Use Castigliano's Second Theorem (neglect shear energy) to determine:

1. Reactions at end A.
2. Slope $\theta$ of the beam at the support C.

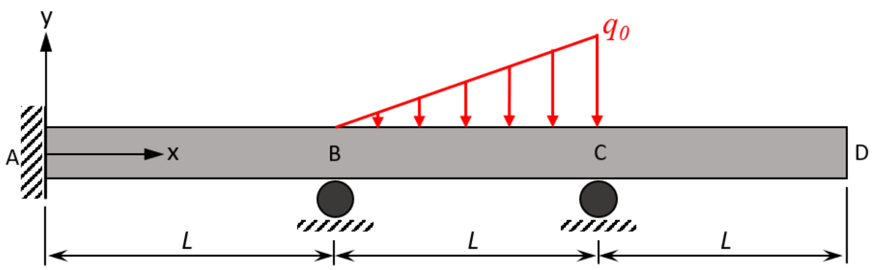



Fig. 7.4

**ME 323 Examination # 2** **Name ______________________________**
**(Print) (Last) (First)**

**PROBLEM #4 (25 Points):**

***PART A – 4 points***

Figure 4A shows a beam that is subjected to point load at multiple locations. The beam has a T-shaped cross section as shown in Figure 4B. Circle the correct answer for the following questions:

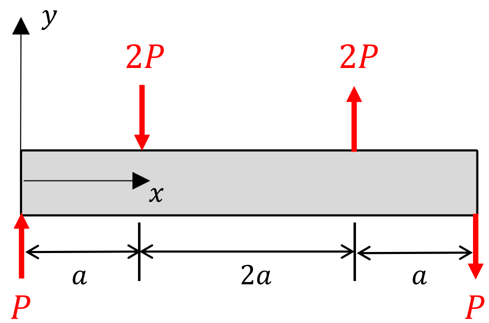



Figure 4A

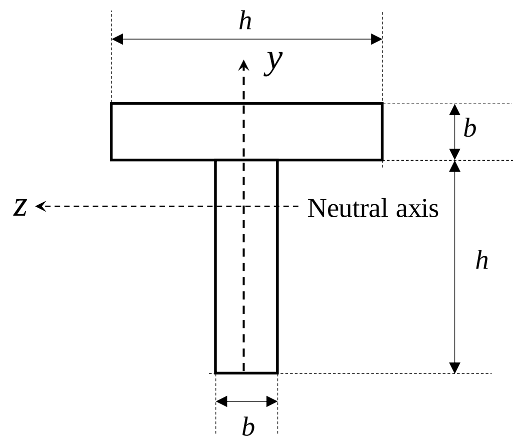



Figure 4B

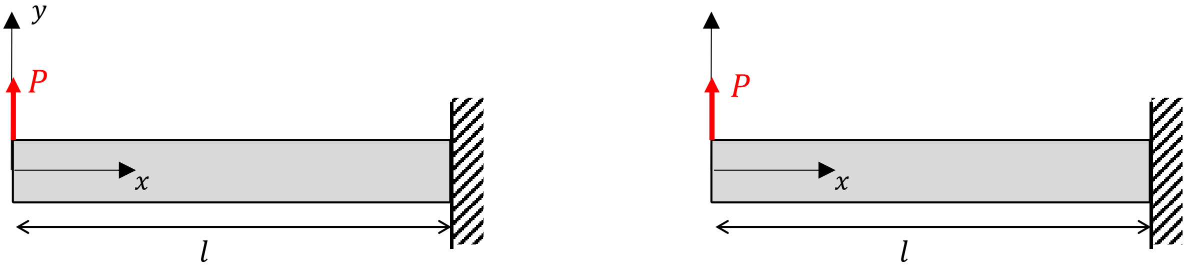
a) On which cross section the maximum tensile stress is attained?
   (1) $x = 0$
   (2) $x = a$
   (3) $x = 2a$
   (4) $x = 3a$
   (5) $x = 4a$

b) On which cross section the maximum compressive stress is attained?
   (1) $x = 0$
   (2) $x = a$
   (3) $x = 2a$
   (4) $x = 3a$
   (5) $x = 4a$

**PROBLEM #4 (cont.):**

***PART B – 9 points***

Beam (i) and (ii) shown below are identical, except that beam (i) is made of steel, and beam (ii) is made of aluminum. Note that $E_{steel} > E_{aluminum}$.




Beam (i) – steel Beam (ii) – aluminum

a) **TRUE** or **FALSE**: The two beams have the same second moment of area.

b) **TRUE** or **FALSE**: The two beams have the same magnitude of the maximum normal stress.

c) **TRUE** or **FALSE**: The two beams have the same magnitude of the maximum shear stress.

d) **TRUE** or **FALSE**: The two beams have the same magnitude of the maximum deflection.

e) Let $v_{max}$ be the maximum deflection in beam (i). If the length of beam (i) increases from its original value $l$ to a new value $2l$, and the same load is applied at the free end. The new value of the maximum deflection becomes $v^*_{max}$. Circle the correct answer:

(1) $v^*_{max} = v_{max}$.

(2) $v^*_{max} = 2v_{max}$.

(3) $v^*_{max} = 4v_{max}$.

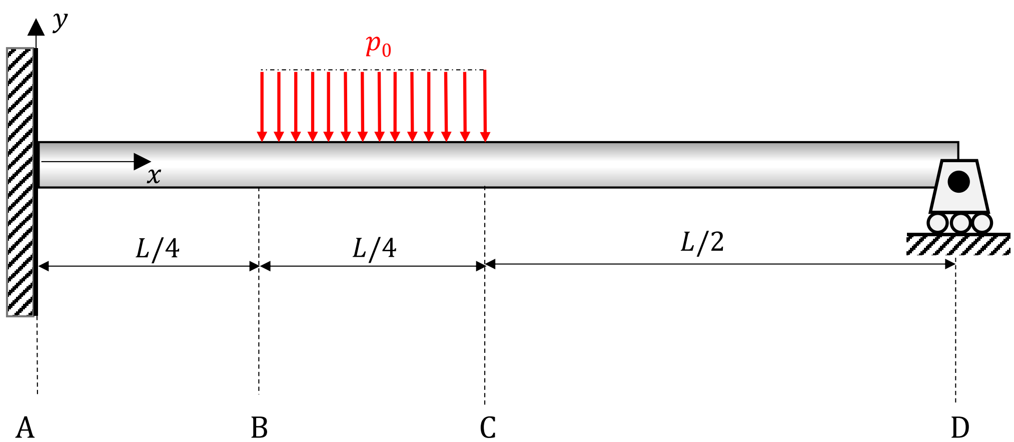
(4) $v^*_{max} = 8v_{max}$.

(5) $v^*_{max} = 16v_{max}$.

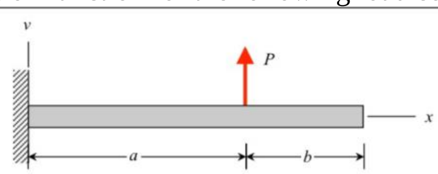
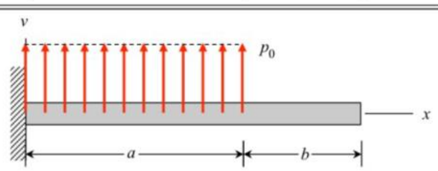
**<u>PROBLEM #4 (cont.)</u>:**

### *PART C – 6 points*

A cantilever beam shown below is supported by a roller at the end D and is subject to a distributed load of the magnitude $p_0$ through the section BC. Use the superposition method to determine the reaction force at the roller D. $L$ = 4m, $p_0$ = 4kN/m.



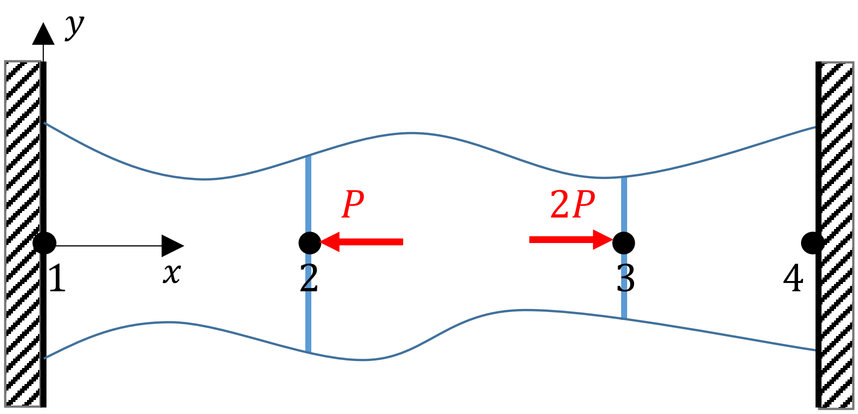

The deflection function for the following load configuration is given:

| | |
|---|---|
|   | $v(x) = \frac{1}{6}\left[x^2(3a - x)\right]\frac{P}{EI}$ ; $0 < x < a$ <br> $= \frac{1}{6}\left[a^2(3x - a)\right]\frac{P}{EI}$ ; $a < x < L$ |
|   | $v(x) = \frac{x^2}{24}\left[6a^2 - 4ax + x^2\right]\frac{p_0}{EI}$ ; $0 < x < a$ <br> $= \frac{a^3}{24}\left[4x - a\right]\frac{p_0}{EI}$ ; $a < x < L$ |

**<u>PROBLEM #4 (cont.)</u>:**

***PART D – 6 points***

The rod shown below has a variable cross section. A finite element model comprising of 3 elements and 4 nodes are shown on the figure. Two concentrated forces $P$ and $2P$ are applied at the nodes 2 and 3, respectively. The concentrated force $P$ = 1000 lb.




The finite element model has the global stiffness matrix as follows:

$$\begin{bmatrix} \_ & -1 & \_ & \_ \\ \_ & \_ & \_ & \_ \\ \_ & \_ & 5 & \_ \\ \_ & \_ & \_ & 3 \end{bmatrix} \times 10^5 \ lb/in$$

a) Determine the remaining 13 matrix elements and fill the blank spaces.
b) Determine the displacement at nodes 2 and 3.
c) Determine the reaction force due to the wall at the node 4.