Name (Print) _____
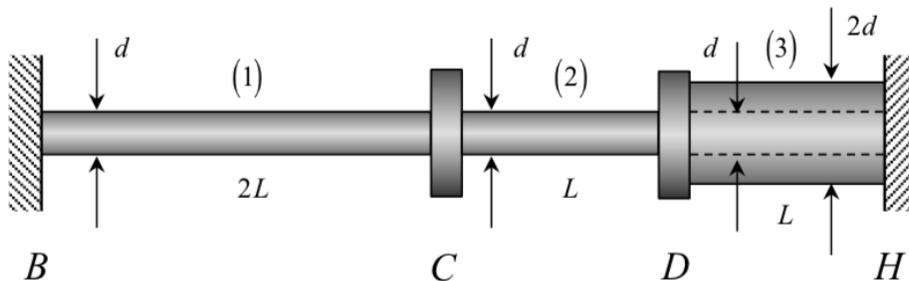
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PROBLEM # 1 (25 points)

A rod is made up of elastic members (1), (2) and (3), with the material makeup of each member having a Young's modulus of E and a coefficient of thermal expansion of α. Members (1), (2) and (3) have lengths of $2L$, L and L, respectively. Members (1) and (2) have solid cross-sections with a diameter of d, whereas member (3) has a tubular cross-section with inner and outer diameters of d and $2d$, respectively. With the members being initially unstressed, the temperatures of (1) and (2) are increased by amounts of $2\Delta T$ and ΔT, respectively, while the temperature of (3) is held constant.

As a result of the temperature changes described above:

a) Determine the axial load (force) carried by each member. State whether each member is experiencing a compressive or tensile load.

b) Determine the axial strain in each member. Include an appropriate sign with each strain.

Leave your answers in terms of, at most, E, α, L, d and ΔT.

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PROBLEM # 1 (cont.)

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PROBLEM # 1 (cont.)

ME 323 – Mechanics of Materials
Examination #1
October 1st, 2020

PURDUE
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Mechanical Engineering

Name (Print) _____

(Last)   (First)

PROBLEM # 2 (25 points)

The critical components for the design of the planar truss in Figure 2a are considered to be member AB and the pin at C (shown in Figure 2b). The truss is subjected to a single downward force P at A. All members of the truss have a cross-sectional area of A=1 in². The cross-sectional area of the pin at C is A_C =0.5 in². The factor of safety (FS) against failure of AB by yielding is FS_{AB}= 3. The factor of safety against ultimate shear failure of the double-sided pin at C is FS_C = 4.

For member AB, σ_Y=36 ksi and for the pin material τ_U=48 ksi.

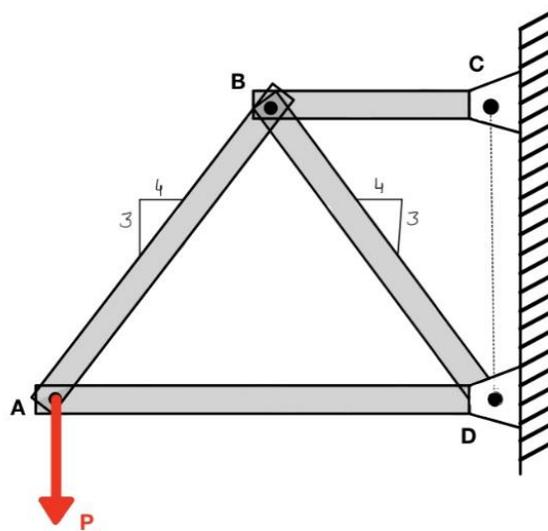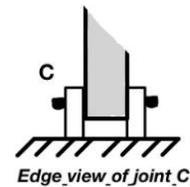Find the largest P that can be applied without failure of the member AB and pin C.

Edge_view_of_joint_C

Figure 2(b)

Figure 2(a)

Name (Print) _____
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PROBLEM # 2 (cont.)

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PROBLEM # 2 (cont.)

ME 323 – Mechanics of Materials
Examination #1
October 1st, 2020

**PURDUE
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Mechanical Engineering

Name (Print) _____
(Last)   (First)

PROBLEM # 3 (25 points)

Shafts (1), (2) and (3) in Fig. 3(a) are connected by a rigid connector at B, and are fixed to the rigid walls at the ends A and C. Shafts (1) and (2) have length $2L$, and shaft (3) has length L. The shear moduli of shafts (1), (2), and (3) are $G_1=15G$, $G_2=G$ and $G_3=8G$, respectively. Shaft (1) has a solid cross section of diameter $2d$, shaft (2) has a hollow cross section of outer diameter $4d$ and inner diameter $2d$, and shaft (3) has a hollow section of outer diameter $2d$ and inner diameter d, as shown in Figs. 3(b) and 3(c). An external torque T_B is applied at the connect B.

a) Determine if the assembly is statically determinate or indeterminate.

b) Determine the internal torque carried by shaft (2).

c) Consider the points "M" and "N" on the outer radius of shaft (2). Draw the stress elements to represent the stress states at "M" and "N".

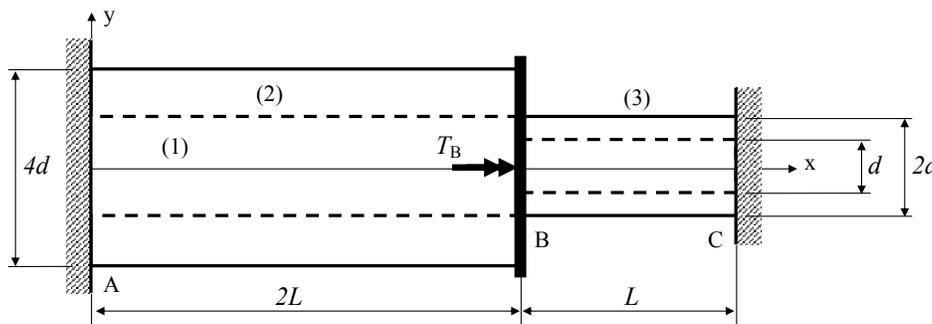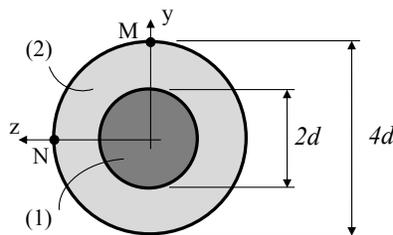Express your results in terms of T_B, d, L, G, and π.
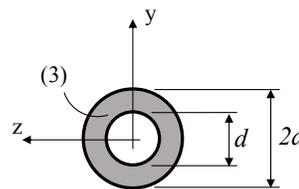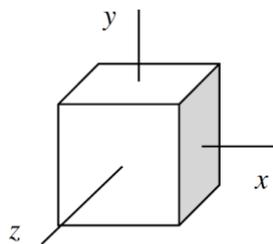
Fig. 3(a)

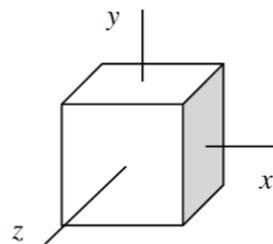Fig. 3(b)   Fig. 3(c)

stress element at M   stress element at N

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Name (Print) _____
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PROBLEM # 3 (cont.)

Name (Print) _____
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PROBLEM # 3 (cont.)

Name (Print) _____

(Last)   (First)

PROBLEM # 4 (25 points – Partial credit may not be granted)

PROBLEM # 4 – PART A (3 points)

A hydraulic punch of diameter d is used to punch circular holes in a plate of thickness t. Upon applying a punch force of P, what is the shear resistance τ of the plate?
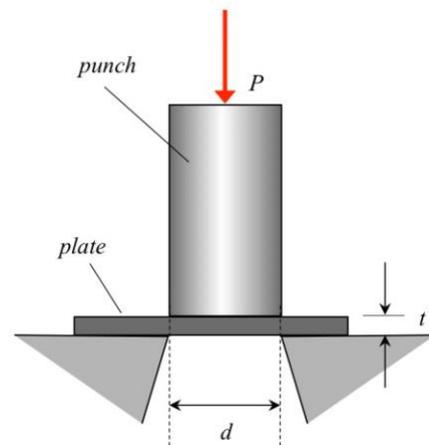
Justify your answer.

(a) $\tau = \dfrac{P}{\frac{\pi}{4}d^2}$

(b) $\tau = \dfrac{P}{\pi dt}$

(c) $\tau = \dfrac{P/2}{\pi dt}$

(d) $\tau = \dfrac{P/2}{\frac{\pi}{4}d^2}$

(e) None of the above

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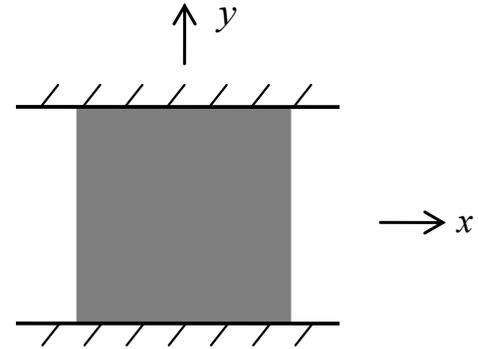
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Name (Print) _____

(Last)   (First)

PROBLEM # 4 – PART B (3 points)

A block is fully constrained in the y direction and is free to expand in the x and z (out of paper) directions. The block is free of stress at the initial temperature T. When the temperature is increased by ΔT, which of the following statements about stresses and strains is correct? The coeffiecient of thermal expansion of the block is α. Young's modulus and Poisson's ratio are E and υ, respectively.

Justify your answer.

(a) $\sigma_x = -\alpha E \Delta T, \ \varepsilon_x = 0, \ \sigma_y = 0, \ \varepsilon_y = \alpha \Delta T$

(b) $\sigma_x = 0, \ \varepsilon_x = \alpha \Delta T, \ \sigma_y = -\alpha E \Delta T, \ \varepsilon_y = -\upsilon \varepsilon_x$

(c) $\sigma_x = 0, \ \varepsilon_x = (1 + \upsilon)\alpha \Delta T, \ \sigma_y = -\alpha E \Delta T, \ \varepsilon_y = 0$

(d) $\sigma_x = -\alpha E \Delta T, \ \varepsilon_x = 0, \ \sigma_y = 0, \ \varepsilon_y = -\upsilon \varepsilon_x$

(e) None of the above

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Name (Print) _____
                   (Last)   **(First)**

PROBLEM # 4 – PART C (7 points)

A stepped shaft is composed of two members (1) and (2). The two members are connected by a rigid connector at B on which an external force F is applied. The shaft is fixed to the wall at A and has a free end at C. Circle TRUE or FALSE for the following statements (No need to justify your answers):
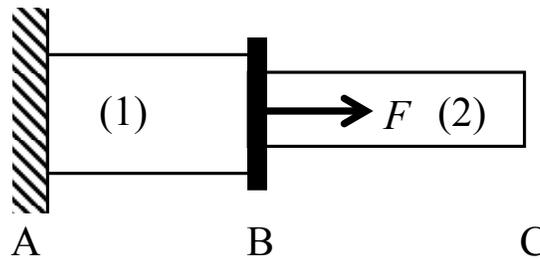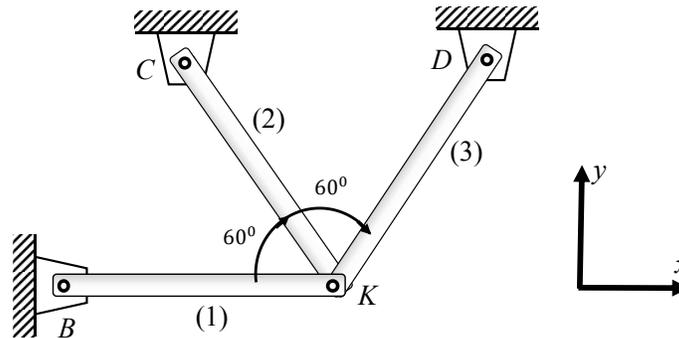

(a) **TRUE** or **FALSE**: The two members have the same internal force.

(b) **TRUE** or **FALSE**: The member (2) is free of stress.

(c) **TRUE** or **FALSE**: The internal forces in the two members are of equal magnitude but different signs.

(d) **TRUE** or **FALSE**: The shaft is a statically indeterminate structure.

(e) **TRUE** or **FALSE**: The two members have the same elongation.

(f) **TRUE** or **FALSE**: The sum of elongations of the two members is zero.

(g) **TRUE** or **FALSE**: Elongation of member (1) is equal to the elongation of the shaft.

Name (Print) _____

(Last)   **(First)**

PROBLEM # 4 – PART D (3 points)

The geometry of deformation in planar truss is given by $e = u\cos\theta + v\sin\theta$, where e represents the elongation of a truss member, u and v are the displacement of the joint K in the x and y directions, respectively. Determine the θ value, in radian, for the members (1), (2), and (3) in the following truss for an arbitrary force applied at the joint K:


$\theta_1 = $ _____

$\theta_2 = $ _____

$\theta_3 = $ _____

ME 323 – Mechanics of Materials
Examination #1
October 1ˢᵗ, 2020

PURDUE
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Mechanical Engineering

Name (Print) _____

(Last)   (First)

PROBLEM # 4 – PART E (3 points)

A rigid bar ABCD is supported by a pin at A, and two rods (1) and (2) as follows. A force P is applied at C. By equilibrium analysis, this structure is found to be statically indeterminate. Which of the following statements represents the correct compatibility condition between the elongation of rod (1) e_1 and elongation of rod (2) e_2?
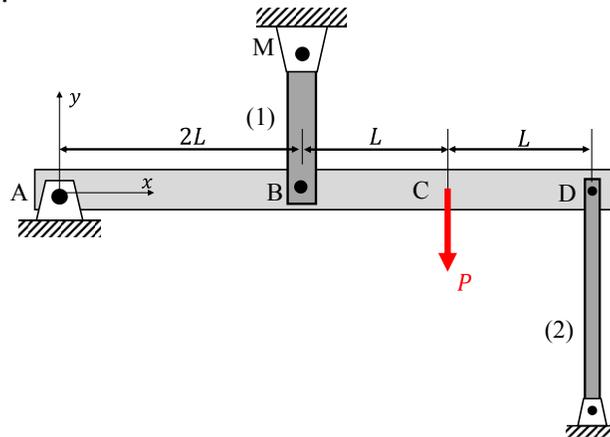

Make a sketch to justify your answer.

    (a) $e_1 = e_2$

    (b) $e_1 = -e_2$

    (c) $e_1 = e_2/2$

    (d) $e_1 + e_2 = 0$

    (e) None of the above

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Name (Print) _____

(Last)   **(First)**

PROBLEM # 4 – PART F (6 points)

A circular bimetallic bar consists of a tubular shell A and a core B. The bimetallic bar is subject to a torque T. The shear moduli of the core and shell are known to be $G_A = 2G_B$, and polar moment of inertia $I_{PA} = 8I_{PB}$. In the cross section *aa,* circle TRUE or FALSE for the following statements (No need to justify your answers):
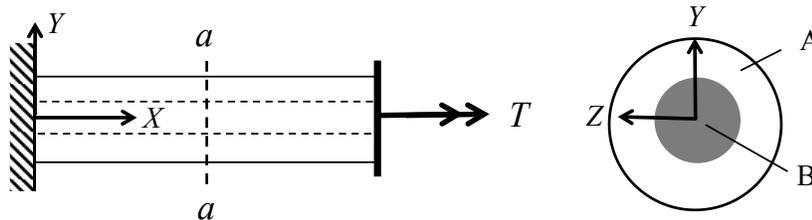
(a) **TRUE** or **FALSE**: The two members experience the same internal torque.

(b) **TRUE** or **FALSE**: The two members experience the same twist angle within the cross section *aa*.

(c) **TRUE** or **FALSE**: The twist angle φ within the cross section *aa* is a linear function of the radial distance.

(d) **TRUE** or **FALSE**: The shear strain distribution (i.e., shear strain as a function of the radial distance) within the cross section *aa* is continuous across the boundary between A and B.

(e) **TRUE** or **FALSE**: The shear stress distribution (i.e., shear stress as a function of the radial distance) within the cross section *aa* is continuous across the boundary between A and B.

(f) **TRUE** or **FALSE**: The shear stress distribution (i.e., shear stress as a function of the radial distance) in A and B on the cross section *aa* has the same slop.