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(Last) **(First)**

ME 323 - Mechanics of Materials
Exam # 1
Date: February 15, 2017 Time: 8:00 – 10:00 PM - Location: WTHR 200

Instructions:

Circle your lecturer's name and your class meeting time.

Koslowski	Zhao	Bi
8:30-9:20AM	11:30-12:20AM	1:30-2:20PM

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.

Remove the staple and restaple, if necessary.

Prob. 1 _____

Prob. 2 _____

Prob. 3 _____

Prob. 4 _____

Total _____

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PROBLEM #1 (22 points)

A solid brass core is connected to a hollow rod made of aluminum. Both are attached at each end to a rigid plate as shown in Fig. 1. The moduli of aluminum and brass are E_A=11,000 ksi, E_B=15,000 ksi, and the coefficients of thermal expansion are $\alpha_A=13\times10^{-6}/°F$, $\alpha_B=12\times10^{-6}/°F$, respetively. The cross section areas of aluminum and brass are A_A=2 in^2 and A_B=1 in^2, respectively. The core and the sleeve are stress free at the reference temperature. If the core is heated by 100°F and the temperature of the sleeve is held constant, calculate:

1) The axial force and average axial stress (x direction) in each member.
2) The elongation of the composite bar in the x direction.
3) What should be the magnitude of the force F in Fig. 1 to prevent the elongation of the composite bar in the x direction?

Hints: Ignore the radial expansion due to Poisson's ratio effect.
For 1) and 2) use F=0

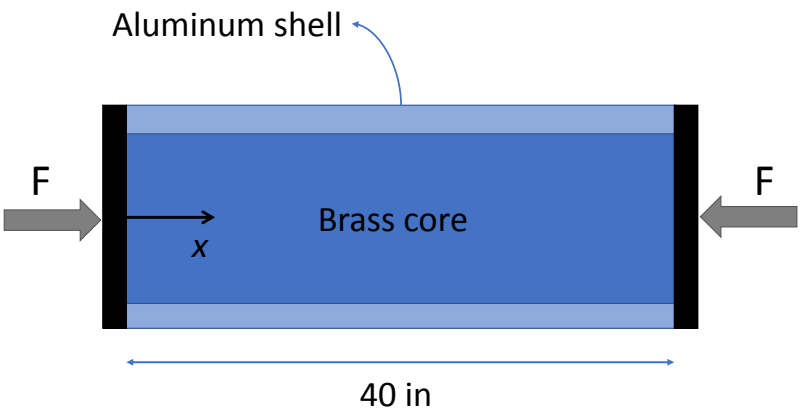

Fig. 1

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PROBLEM #2 (28 points)

A shaft is made up of three components: solid circular shafts (1) of length 2*L* and diameter *d*; solid circular shaft (2) of length *L* and diameter 2*d*; and *tubular* shaft (3) of length *L*, outer diameter 3*d* and inner diameter 2*d*. All three components are made of the same material having a shear modulus of *G*. Shafts (1) and (2) are connected by a thin, rigid connector C, whereas shafts (2) and (3) are connected by a rigid connector D. Shaft (1) is rigidly attached to ground at B. Shaft (3) is rigidly attached to ground at H. Torques *T* and 2*T* are applied to C and D, respectively, as shown in the Fig. 2 (a).

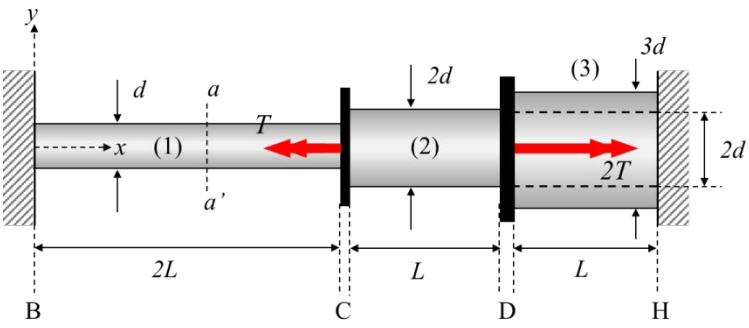

Fig. 2 (a)

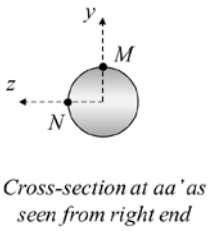

Fig. 2 (b)

Fig. 2 (c)

1) Determine the torque carried by each of the shaft components.
2) Determine the angle of rotation at connector C.
3) Show the stress element for the points M (x, 0.5d, 0) and N (x, 0, 0.5d), whose locations on shaft (1) are also shown on Fig. 2 (b). Indicate both magnitudes and axes corresponding to the state of stress on Fig. 2 (c).
Express your final answers in terms of *T*, *L*, *d* and *G*.

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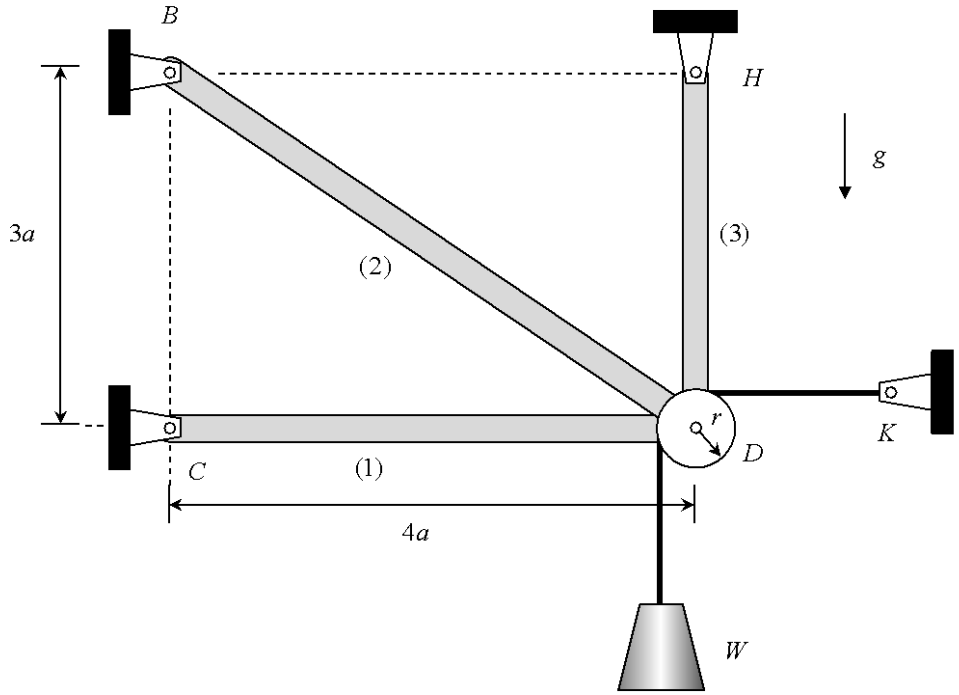
PROBLEM #3 (26 points)

A truss is made up of members (1)-(3), with each member having a cross-sectional area of *A* and being made up of a material with a Young's modulus of *E*. Members (1)-(3) are connected to ground at pins C, B and H, respectively, and are connected together at pin D. A frictionless pulley is also attached to pin D. A block of weight *W* is supported by a cable that is pulled over the pulley and attached to ground at K. Pins B, C and H each have a cross-sectional diameter of *d*, and have a "*single-sided*" connection to ground. The pins are made of a material having a shear yield strength of τ_Y.

a) Determine the load carried by each member of the truss. Express your final answers in terms of, at most, *A*, *E*, *W* and *a*.

b) Determine the largest *W* that can be supported by the truss without failure at pins B, C or H. Use a factor of safety of FS= 2.



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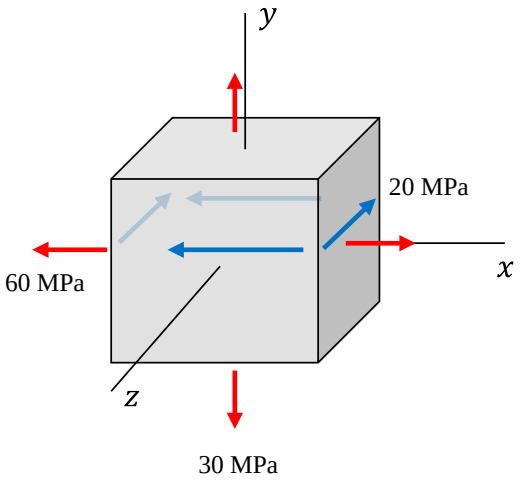
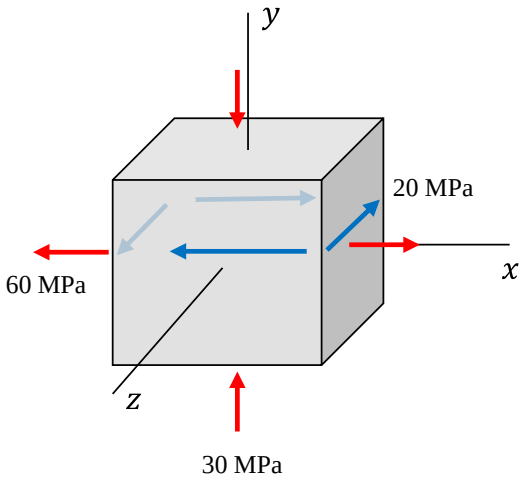
PROBLEM #4 (24 Points):

4.1. (8 Points)

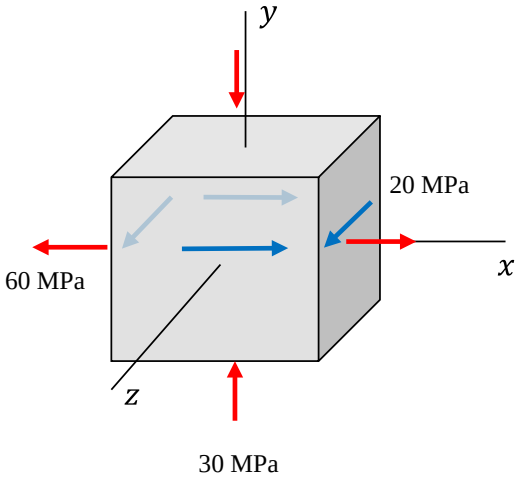
A material point in a steel machine is subjected to the following stress state: $\sigma_x = 60$ MPa , $\sigma_y = -30$ MPa , and $\tau_{xz} = -20$ MPa . Which of the following stress elements represents the correct stress state of the material point?



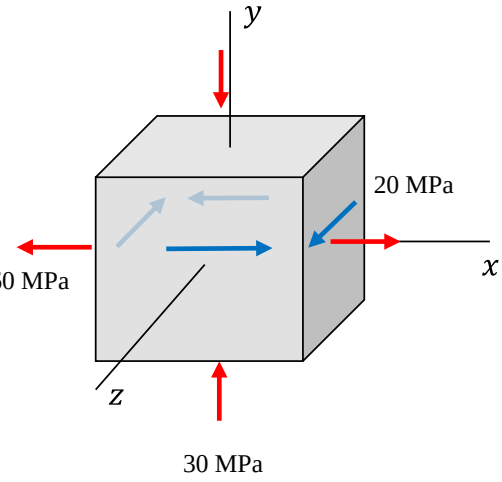
(a)



(b)



(c)



(d)

Using E=210 GPa and ν=0.3 for steel, $G = \dfrac{E}{2(1+\nu)}$, determine the strain components:

ε_x = _____

ε_y = _____

ε_z = _____

γ_{xy} = _____

γ_{yz} = _____

$\gamma_{xz} =$ _____

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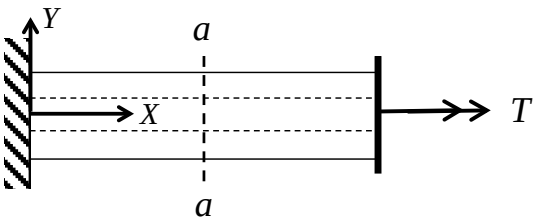
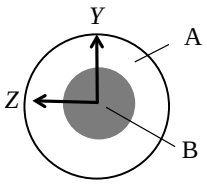
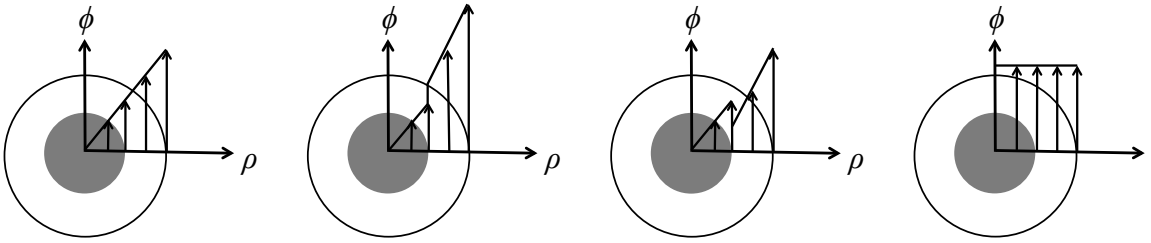
4.2. (6 Points)

A bimetallic bar with circular cross section consists of a shell A and a core B. The bimetallic bar is subjected 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 $I_{PA} = 0.5\, I_{PB}$.

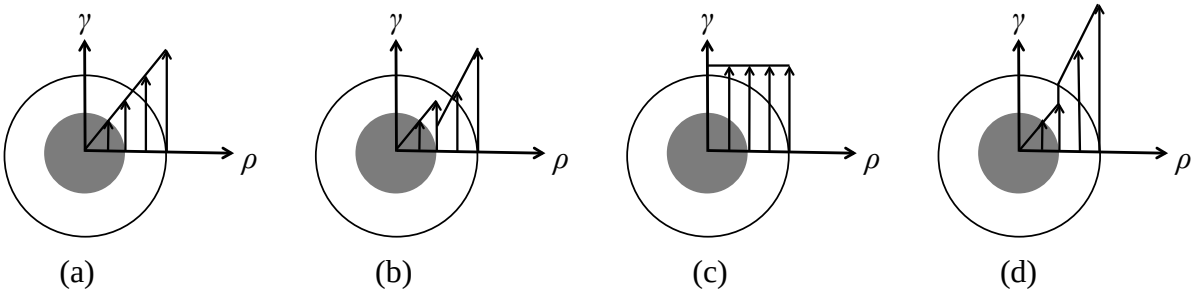




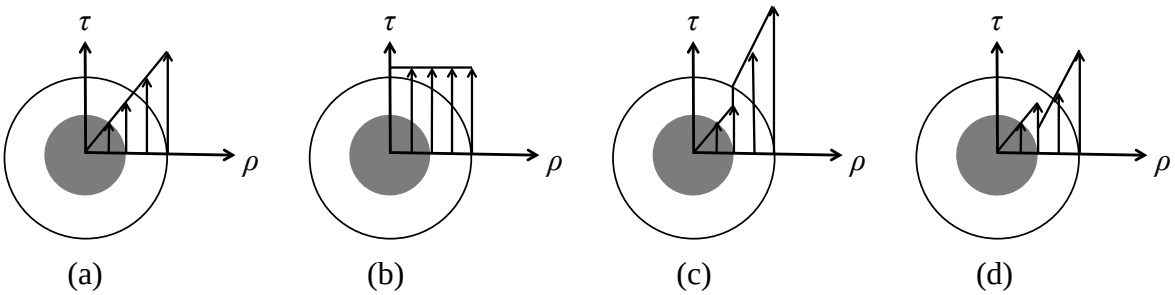
Which figure shows the correct distribution of the twist angle in the cross section *aa*?



Which figure shows the correct distribution of the shear strain in the cross section *aa*?



Which figure shows the correct distribution of the shear stress in the cross section *aa*?



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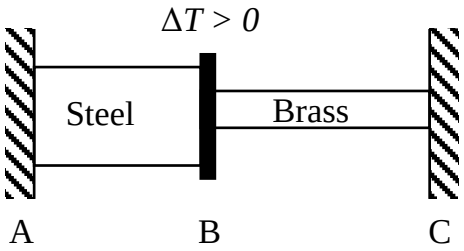
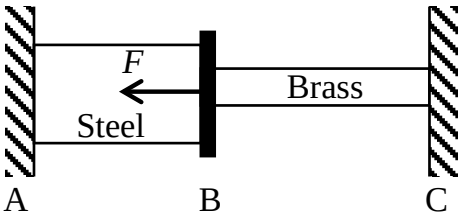
4.3. (10 Points)

A stepped rod is composed of steel and brass that are joined by a rigid connector at B and are fixed at the two ends. The coefficients of thermal expansion for steel and brass are α_S and α_B ($\alpha_s > \alpha_B$), respectively. Consider two load conditions shown below, the rod is homogeneously heated with a temperature increase of ΔT in (1), and a force F is applied at the rigid connector while temperature is held constant in (2). Which of the following statements are correct? (More than one item can be selected)



(1)



(2)

(a) Both configurations (1) and (2) are statically indeterminate structures.

(b) (1) is a statically determinate structure and (2) is a statically indeterminate structure.

(c) The forces F_S (steel) and F_B (brass) in (1) are both zero

(d) The forces F_S (steel) and F_B (brass) in (1) are non-zero and are equal.

(e) The forces F_S (steel) and F_B (brass) in (1) are equal in magnitude and of opposite signs.

(f) The strains ε_S (steel) and ε_B (brass) in (1) are both zero.

(g) The strains ε_S (steel) and ε_B (brass) in (1) are non-zero and are equal.

(h) The strains ε_S (steel) and ε_B (brass) in (1) are equal in magnitude and of opposite signs.

(i) The stresses σ_S (steel) and σ_B (brass) in (1) are both compressive.

(j) The stresses σ_S (steel) and σ_B (brass) in (1) are equal in magnitude and of opposite signs.

(k) The forces F_S (steel) and F_B (brass) in (2) are non-zero and are equal.

(l) The forces F_S (steel) and F_B (brass) in (2) are both compressive.

(m) The elongations e_S (steel) and e_B (brass) in (2) are equal.

(n) The elongations e_S (steel) and e_B (brass) in (2) are equal in magnitude and of opposite signs.

(o) The stresses σ_S (steel) and σ_B (brass) in (2) are equal in magnitude and of opposite signs.

(p) The solution of the stresses σ_S (steel) and σ_B (brass) in (2) depends on the cross sections, lengths, and elastsic moduli of steel and brass.

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