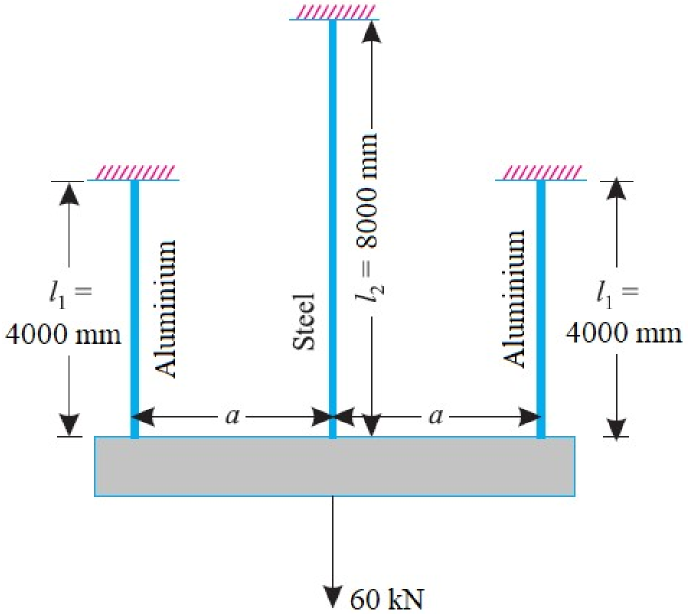
VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

SLOT: C1+TC1

SCHOOL OF MECHANICAL ENGINEERING
CONTINUOUS ASSESSMENT TEST – I
FALL SEMESTER 2023-2024

Programme Name & Branch	**: B.Tech. (Mechanical/Automotive)**
Course Code	**: BMEE202L**
Course Name	**: Mechanics of Solids**
Faculty Name(s)	**: SHARAN CHANDRAN M, VENKATESAN S, VASUDEVAN R, AKASH MOHANTY, YAGNA S MUKKAMALA, SOVAN SUNDAR DASGUPTA**
Class Number(s)	**: VL2023240101687/ 1694/1691/1690/1693/1689**
Exam Duration	**: 90 minutes** **Maximum Marks: 50**

General instruction(s): Answer all the questions. Assume the missing data (if any). Answer to-the-point and tabulate your final results.

Q. No	Question	Marks
1.	If a load of 60 kN is applied to a rigid bar suspended by three wires as shown in Figure 1, what force will be resisted by each wire? The outside wires are of aluminium, cross-sectional area 300 mm^2 and length 4 m. The central wire is steel, with area 200 mm^2 and length 8 m. Initially, there is no slack in the wires. E is 200 GPa for steel and 66 GPa for aluminium.  Fig. No. 1	10
2.	A copper rod of 6 cm in diameter is placed within a steel tube of 8 cm external diameter and 6 cm internal diameter of exactly the same length (Figure 2). The two pieces are rigidly fixed together by two transverse pins 20 mm in diameter, one at each end, passing through both the rod and the tube. Calculate the stresses induced in the copper rod, steel tube, and pins if the temperature of the combination is raised by 50 ^oC. Take E_s = 210 GPa, α_s = 0.0000115 /^oC; E_c = 105 GPa, α_c = 0.000017 /^oC.	10

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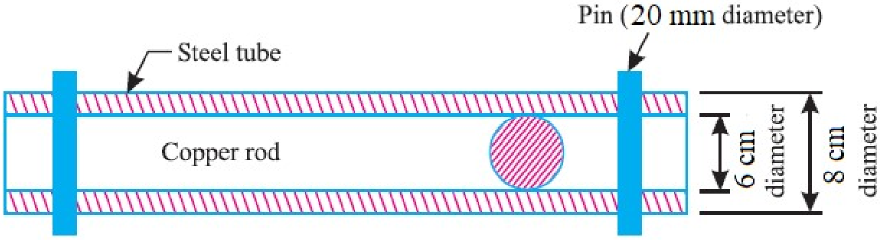

Fig. No. 2

3.	A circular rod of 25 mm diameter and 500 mm length is subjected to a tensile force of 60 kN. Determine the modulus of rigidity, bulk modulus, and change in volume if Poisson's ratio is 0.3 and Young's modulus E is 200 GPa.	10
4.	A prismatic bar of 500 mm^2 cross-sectional area is axially loaded with a tensile force of 50 kN. Determine all the stresses acting on an element that has a 30° inclination with the vertical plane.	10
5.	In the wall of a cylinder the state of stress is given by, σ_x = 85 MPa (compressive), σ_y = 25 MPa (tensile) and shear stress τ_{xy} = 60 MPa. Using the graphical method, calculate (i) the principal stresses and corresponding orientation of principal planes on which they act and (ii) Maximum shear stress and the planes on which they act.	10

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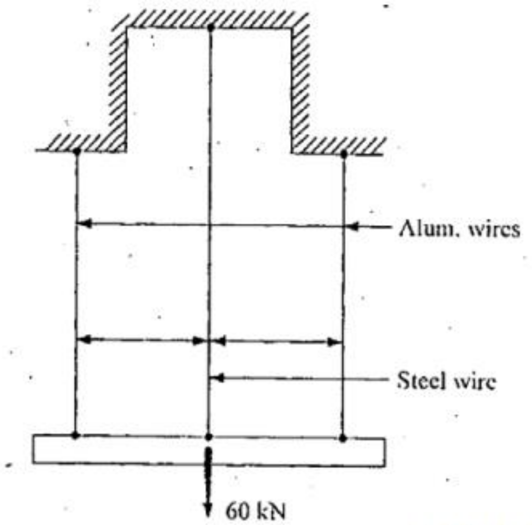
SCHOOL OF MECHANICAL ENGINEERING
CONTINUOUS ASSESSMENT TEST – I
FALL SEMESTER 2023-2024

Programme Name & Branch: B.Tech, Mechanical
Course Code: BMEE202L
Course Name: MECHANICS OF SOLIDS
Faculty Name(s):
Class Number(s):
Exam Duration: 90 minutes **Maximum Marks: 50**

General instruction(s):

Q.No	Question	Marks
1.	If a load of 60 kN is applied to a rigid bar suspended by 3 wires as shown in the above figure what force will be resisted by each wire? The outside wires are of Al, crosssectional area 300 mm^2 and length 4 m. The central wire is steel with area 200 mm^2 and length 8 m. Initially there is no slack in the wires . E = 200 GPA for Steel and 66 GPa for Aluminum. 	10

SLOT: C1+TC1

SCHOOL OF MECHANICAL ENGINEERING
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<table>
<tr>
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<td>$P = 60\ kN$
$a_{A1} = 300\,mm^2 \quad l_{A1} = 4\,m$
$a_{st} = 200\,mm^2 \quad l_{st} = 8\,m$
$E_{A1} = 0.667 \times 10^5 N/mm^2$
$E_{st} = 2 \times 10^5 N/mm^2$
Force balance along vertical direction
$2F_{A1} + F_{st} = 60\ kN$ (1)
Elongation will be same in all wires because rod is rigid remain horizontal
$\frac{F_{A1} \times l_{A1}}{a_{A1}.E_{A1}} = \frac{F_{st}.l_{st}}{a_{st}.E_{st}}$ (2)
$\frac{F_{A1} \times 4}{300 \times 0.667 \times 10^5} = \frac{F_{st} \times 8}{200 \times 2 \times 10^5}$
$F_{A1} = 1.0005\ F_{st}$ (3)

From equation (1) $F_{st} = \frac{60 \times 10^3}{3.001} = 19.99\ kN\ or\ 20\ kN$
$F_{A1} = 20\ kN$
$\left.\begin{array}{l} F_{A1} = 20\ kN \\ F_{st} = 20\ kN \end{array}\right\}$ Answer.</td>
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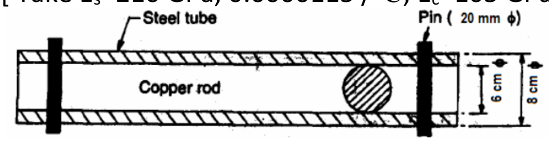
<tr>
<td>2.</td>
<td>A Copper rod 6 cm in diameter is placed within a steel tube, 8 cm external diameter and 6 cm internal diameter, of exactly the same length. The two pieces are rigidly fixed together by two transverse pins 20 mm in diameter, one at each end passing through both rod and the tube.
Calculate the stresses induced in the copper rod, steel tube and the pins if the temperature of the combination is raised by 50 ℃.
[Take E_s=210 GPa, 0.0000115 /℃; E_c=105 GPa, 0.000017 /℃]

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$$\frac{\sigma_c}{E_c}+\frac{\sigma_s}{E_s}=\Delta t(\alpha_c-\alpha_s)$$

Area of copper rod$(A_c)=\frac{\pi d^2}{4}=\frac{\pi}{4}\left(\frac{6}{100}\right)^2 m^2=2.8274\times10^{-3}m^2$

Area of steel tube $(A_s)=\frac{\pi d^2}{4}=\frac{\pi}{4}\left[\left(\frac{8}{100}\right)^2-\left(\frac{6}{100}\right)^2\right]m^2=2.1991\times10^{-3}m^2$

Rise in temperature, $\Delta t=50°C$

Free expansion of copper bar$=\alpha_c L\Delta t$

Free expansion of steel tube $=\alpha_s L\Delta t$ Page 46 of 429

Difference in free expansion $=(\alpha_c-\alpha_s)L\Delta t$

$=(17-11.5)\times10^{-6}\times L\times50=2.75\times10^{-4}L\,m$

A compressive force (P) exerted by the steel tube on the copper rod opposed the extra expansion of the copper rod and the copper rod exerts an equal tensile force P to pull the steel tube. In this combined effect reduction in copper rod and increase in length of steel tube equalize the difference in free expansions of the combined system.

Reduction in the length of copper rod due to force P Newton=

$$(\Delta L)_C=\frac{PL}{A_cE_c}=\frac{PL}{(2.8275\times10^{-3})(105\times10^9)}\text{m}$$

Increase in length of steel tube due to force P

$$(\Delta L)_S=\frac{PL}{A_sE_s}=\frac{P.L}{(2.1991\times10^{-3})(210\times10^9)}m$$

Difference in length is equated

$$(\Delta L)_c+(\Delta L)_s=2.75\times10^{-4}L$$

$$\frac{PL}{(2.8275\times10^{-3})(105\times10^9)}+\frac{P.L}{(2.1991\times10^{-3})(210\times10^9)}=2.75\times10^{-4}L$$

Or P = 49.695 kN

Stress in copper rod, $\sigma_c=\frac{P}{A_c}=\frac{49695}{2.8275\times10^{-3}}$MPa=17.58MPa

Stress in steel tube, $\sigma_s=\frac{P}{A_s}=\frac{49695}{2.1991\times10^{-3}}\text{MPa}=22.6\text{MPa}$

Since each of the pin is in double shear, shear stress in pins (τ_{pin})

$$=\frac{P}{2\times A_{pin}}=\frac{49695}{2\times\frac{\pi}{4}(0.02)^2}=79\text{ MPa}$$

3. A circular rod of 25 mm diameter and 500 mm long is subjected to a tensile force of 60 kN. Determine modulus of rigidity, bulk modulus and change in volume if Poisson's ratio = 0.3 and Young's modulus E = 200 GPa — 10

. A circular rod of 25 mm diameter and 500 mm long is subjected to a tensile force of 60 kN. Determine modulus of rigidity, bulk modulus and change in volume if Poisson's ratio = 0.3 and Young's modulus E = 2 × 10⁵ N/mm².

Solution: From the relationship

$$E=2G(1+\mu)=3k(1-2\mu)$$

We get, $$G=\frac{E}{2(1+\mu)}=\frac{2\times10^5}{2(1+0.3)}=\mathbf{0.7692\times10^5\ N/mm^2}$$

and $$K=\frac{E}{3(1+2\mu)}=\frac{2\times10^5}{3(1-2\times0.3)}=\mathbf{1.667\times10^5\ N/mm^2}$$

$$\text{Longitudinal stress}=\frac{P}{A}=\frac{60\times10^3}{\frac{\pi}{4}\times25^2}=122.23\text{ N/mm}^2$$

$$\text{Linear strain}=\frac{\text{Stress}}{E}=\frac{122.23}{2\times10^5}=61.115\times10^{-5}$$

Lateral strain $=e_y=-\mu e_x$ and $e_z=-\mu e_x$

Volumetric strain $e_v=e_x+e_y+e_z$

$$=e_x(1-2\mu)$$
$$=e_v\quad=61.115\times10^{-5}(1-2\times0.3)$$
$$=24.446\times10^{-5}$$

but $\frac{\text{Change in volume}}{v}$

$\therefore$ **Change in volume** $=e_v\times v$

$$=24.446\times10^{-5}\times\frac{\pi}{4}\times(25^2)\times500$$

$$=\mathbf{60\ mm^3}$$

4. A prismatic bar of 500 mm^2 cross sectional area is axially loaded with a tensile force of 50 kN. Determine all the stresses acting on an element which makes 30° inclination with the vertical plane. — 10

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<table>
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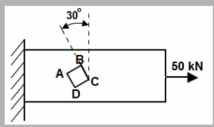
Answer: Take an small element ABCD in 30⁰ plane as shown in figure below,

Given, Area of cross-section, A = 500 mm², Tensile force (P) = 50 kN



Normal stress on 30° inclined plane, $(\sigma_n)=\frac{P}{A}\cos^2\theta=\frac{50\times10^3\,N}{500\ mm^2}\times\cos^2 30^\circ=75MPa$ (+ive means tensile).

Shear stress on 30° planes, $(\tau)=\frac{P}{2A}\sin 2\theta=\frac{50\times10^3 N}{2\times500\ mm^2}\times\sin(2\times30^\circ)=43.3MPa$

(+ive means clockwise)

Complementary stress on $(\theta)=90+30=120^\circ$

Normal stress on 120⁰ inclined plane, $(\sigma_n')=\frac{P}{A}\cos^2\theta=\frac{50\times10^3 N}{500mm^2}\times\cos^2 120^\circ=25MPa$

(+ ive means tensile)

Shear stress on 120⁰ nclined plane, $(\tau')=\frac{P}{2A}\sin 2\theta=\frac{50\times10^3 N}{2\times500mm^2}\times\sin(2\times120^\circ)=-43.3MPa$

(- ive means counter clockwise)

State of stress on the element ABCD is given below (magnifying)

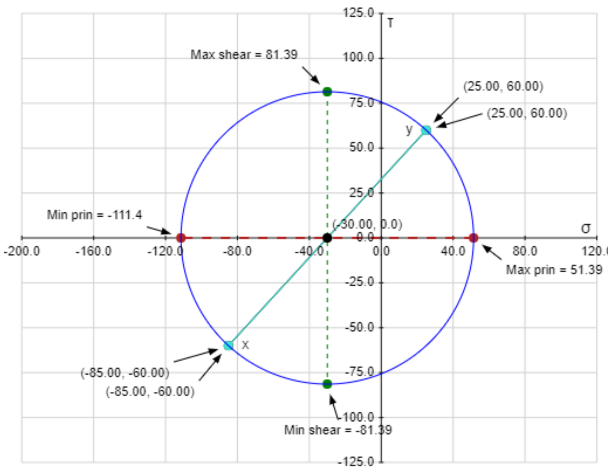
</td><td></td></tr>
<tr><td>5.</td><td>

In the wall of a cylinder the state of stress is given by, σ_x=85MPa (compressive), σ_y= 25MPa (tensile) and shear stress τ_{xy} = 60MPa

Calculate (i) the principal stresses and corresponding orientation of principal planes on which they act.

(ii)Maximum shear stress and the planes on which they act.

(Only graphically)



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</table>

Results

	Value	Angle [deg]
Rotated Element, Normal Stress X	-85.00	0.000°
Rotated Element, Normal Stress Y	25.00	90.00°
Rotated Element, Shear Stress	60.00	---
Max Principal Stress	51.39	66.26°
Min Principal Stress	-111.4	156.3°
Max Extreme Shear Stress	81.39	111.3°
Min Extreme Shear Stress	-81.39	201.3°