The University of Zambia
School of Engineering
Department of Civil and Environmental Engineering
CEE 3211 – Mechanics of Materials Test (2024)

Instructions

Attempts all four questions. All Questions Carry equal marks

Duration: 2 hours

Q1. The assembly consists of two 25-mm-diameter steel (E_S = 200 GPa) rods (AB and CD, a 35-mm-diameter aluminium (E_{al} = 70 GPa) rod EF, and a rigid bar AEC. With the loads applied as shown, determine the **overall displacement** of end **F** of rod EF.

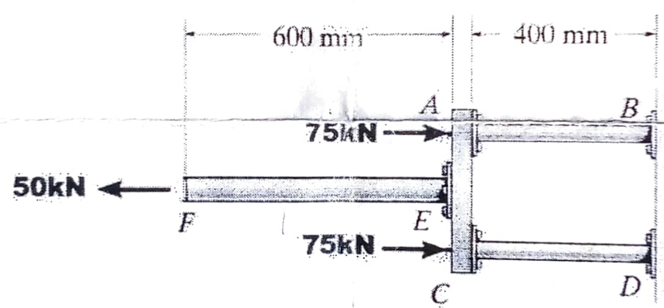


Fig Q1

Q2 A composite cylindrical rod, ABCD consists of bar 1, Steel (E = 207 GPa) and Bar 2, Brass (E = 101 GPa) fixed at both ends as shown in Figure Q2. The member has a gap of 4mm as shown. The thermal coefficient of expansion for steel and brass coefficient as 11.7×10^{-6}/°C and 18×10^{-6}/°C respectively. The composite rod is subjected to a temperature rise of 130°C. Assuming the rod is initially unstressed: Take length AB=600mm and CD = 900mm. Area for steel and brass are 275mm² and 390mm².

a. Calculate the **stress induced** in both bars AB and CD

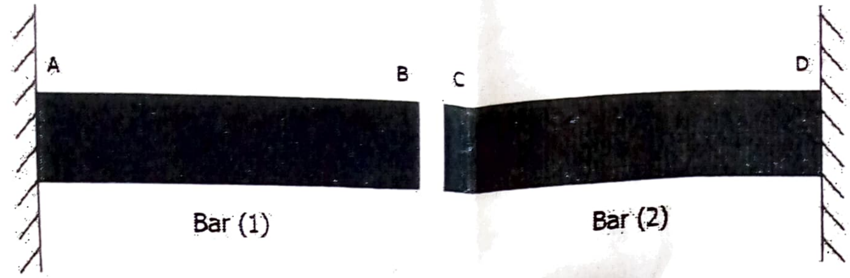


Fig Q2

Q3 A steel beam of 6m in length has a channel cross-section shown in Figure Q3 with two-point loads.

a. Draw the shear and moment diagrams
b. Calculate the **maximum compressive** and **tensile** stresses. Take E_{st} as 200 GPa.

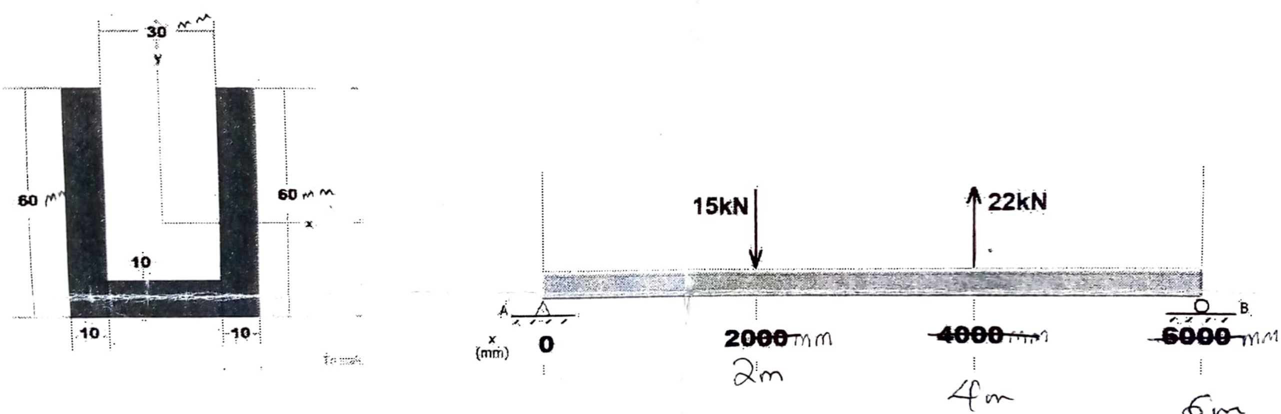


Fig. Q3

Q4. A shaft shown in Figure Q4 has shaft 1 made of solid steel (G = 76 GPa) and Titanium (G = 45 GPa) shaft (2). Shaft 1 has a length of 100mm, and a diameter of 50mm, while shaft 2 has a length of 130mm and a diameter of 30mm.

If an external torque T_B = 800 N.m is applied at point B as shown, calculate the torque T_C required at point C so that the rotation angle of point C relative to A is **zero**.

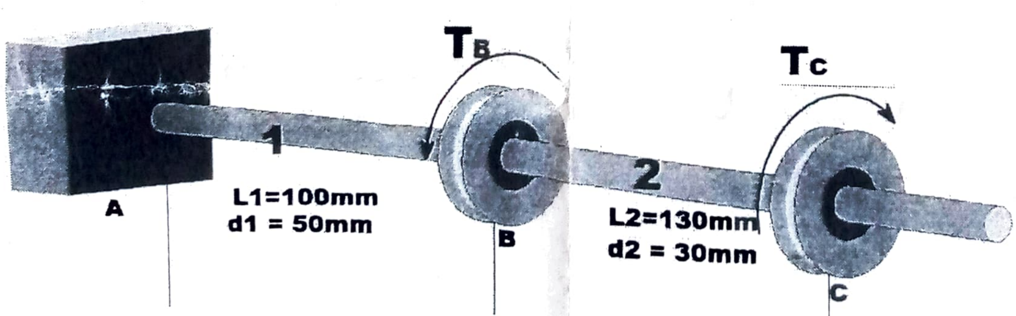


Fig Q4

THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPT. CIVIL & ENVIRONMENTAL ENGINEERING

CEE 3211

MECHANICS OF MATERIALS

[TEST SOLUTIONS]

2024

3211 Test one (2024)

Q1.

$P_{EF} = 50\times10^3 N$ (Tension)

Data

Steel (AB & CD)

$D = 25mm$

$E = 200\times10^3$

Aluminium (EF)

$D = 35mm$

$E = 70\times10^3$

$$P_{AB/CD} = \frac{50KN}{2} - 75KN$$

$$= 25KN - 75KN$$

$$= -50KN$$

$$= -50\times10^3 N \text{ (Compression)}$$

$$\delta_T = \delta_{EF} + \delta_{AB}$$

$$\delta_T = \frac{P_{EF}L}{AE_{EF}} + \frac{P_{AB}L}{AE_{AB}}$$

$$\delta_T = \frac{(50\times10^3N)\times(600mm)\times4}{[\pi.(35)^2]\times[70\times10^3]} + \frac{(-50\times10^3N)\times(400)\times4}{[\pi.(25)^2]\times[200\times10^3]}$$

$$\delta_T = \frac{60\times10^6\times2}{269,391,570} - \frac{40\times10^6\times2}{392,699,081.7}$$

$$\delta_T = \frac{120\times10^6}{269,391,570} - \frac{80\times10^6}{392,699,081.7}$$

$$\delta_T = 0.445448237mm - 0.203718327mm$$

$$\delta_T = 0.241729909 mm$$

$$\therefore \delta_T = 0.242 mm$$

Q2:

$$\delta_{\text{due to } \Delta T} = \delta_{AB} + \delta_{CD}$$

$$\delta = \alpha \Delta T L + \alpha \Delta T L$$

$$\delta = \alpha \Delta T L + \alpha \Delta T L$$

$$\delta = (11.7 \times 10^{-6} \times 130 \times 600) + (18 \times 10^{-6} \times 130 \times 900)$$

$$\delta = 0.9126\,mm + 2.106\,mm$$

$$\delta = 3.0186\,mm$$

Data

Bar 1 (steel) AB

$E = 207 \times 10^3$

$\alpha = 11.7 \times 10^{-6}$

$L_{AB} = 600\,mm$

$A_{AB} = 275\,mm^2$

Bar 2 (Brass) CD

$E = 101 \times 10^3$

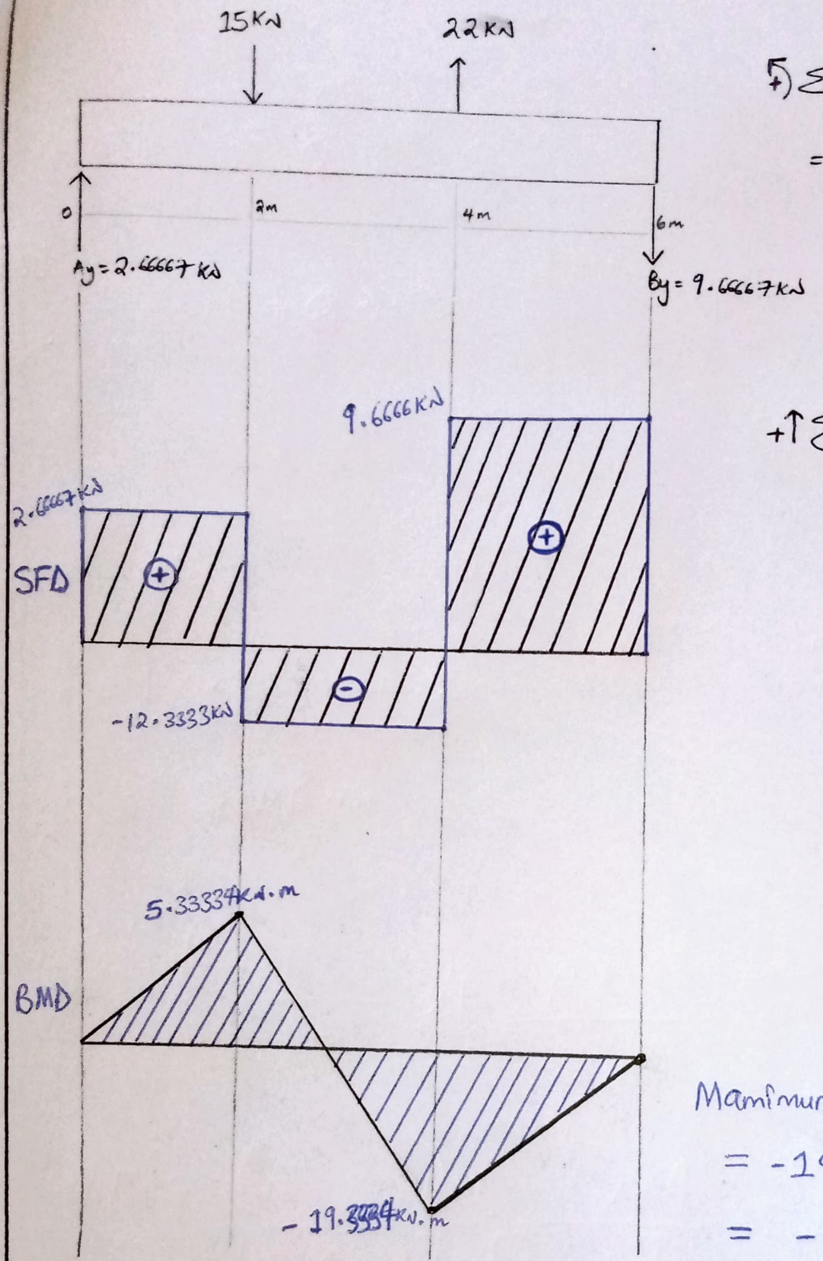
$\alpha = 18 \times 10^{-6}$

$L_{CD} = 900\,mm$

$A_{CD} = 390\,mm^2$

Since ($\delta_{\text{due to temp}}$) is less than 4 mm, then there won't be any stress induced in the bars.

Q3.



$\circlearrowleft^{+} \sum M_A = -15(2) + 22(4) - By(6) = 0$

$= -30 + 88 - By = 0$

$-By(6) = -58$

$-By(6) = -58$

$By = 9.66667\ KN$

$+\uparrow \sum F_y = Ay + 22KN - 15KN - By = 0$

$Ay + 22KN - 15KN - 9.66667 KN = 0$

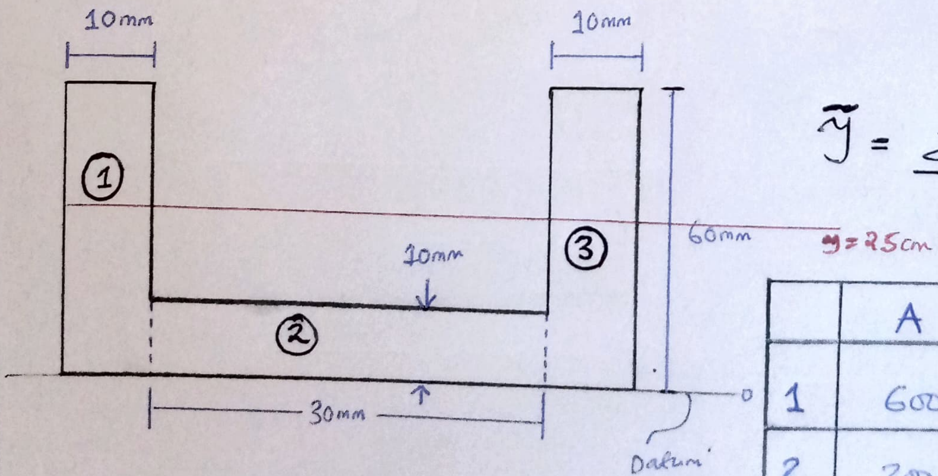
$Ay - 2.66667 KN = 0$

$Ay = 2.66667\ KN$

Maximum Bending moment = -19.3334 KN.m

$= -19.3334$ KN.m

$= -19,333,400$ N.mm



$$\bar{y} = \frac{\sum A\bar{y}}{\sum A}$$

	A	$\bar{y}$	$A\bar{y}$
1	600mm	30 mm	18,000 mm
2	300 mm	5 mm	1,500 mm
3	600 mm	30 mm	18,000 mm
$\sum$	1,500mm		37,500mm

$$\tilde{y}_{c.s} = \frac{37,500\ mm}{1,500\ mm}$$

$\tilde{y}_{c.s} = 25\ mm$

$I = I_1 + I_2 + I_3$

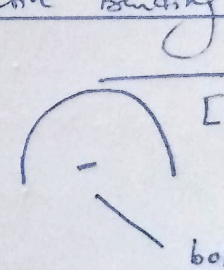
I_1	I_2	I_3
$I_1 = \frac{1}{12} bh^3 + Ad^2$	$I_2 = \frac{1}{12} bh^3 + Ad^2$	$I_3 = \frac{1}{12} \times (10)(60)^3 + (60\times10)(5)^2$
$I_1 = \frac{1}{12} \times (10)(60)^3 + (60\times10)(5)^2$	$I_2 = \frac{1}{12}(30\times10^3) + (30\times10)(20)^2$	$I_3 = 180{,}000 + 15000$
$I_1 = \frac{1}{12}(10\times60^3) + (60\times10)(5)^2$	$I_2 = 2{,}500 + 120{,}000$	$I_3 = 195{,}000\ mm^4$
$I_1 = 180{,}000 + 15{,}000$	$I_2 = 122{,}500\ mm^4$	
$I_1 = 195{,}000\ mm^4$		

$I = I_1 + I_2 + I_3$

$I = 195{,}000\ mm^4 + 122{,}500\ mm^4 + 195{,}000\ mm^4$

$I = 512{,}500\ mm^4$

negative Bending moment



$\sigma_{top} = \frac{Mc}{I}$

$\sigma_{top} = \frac{19{,}333{,}400\ N.mm \times 35mm}{512{,}500\ mm^4}$

$\sigma_{top} = 1320.329756\ MPa$

$\sigma_{maximum\ Tensile} = 1320.33 MPa\ (T)$

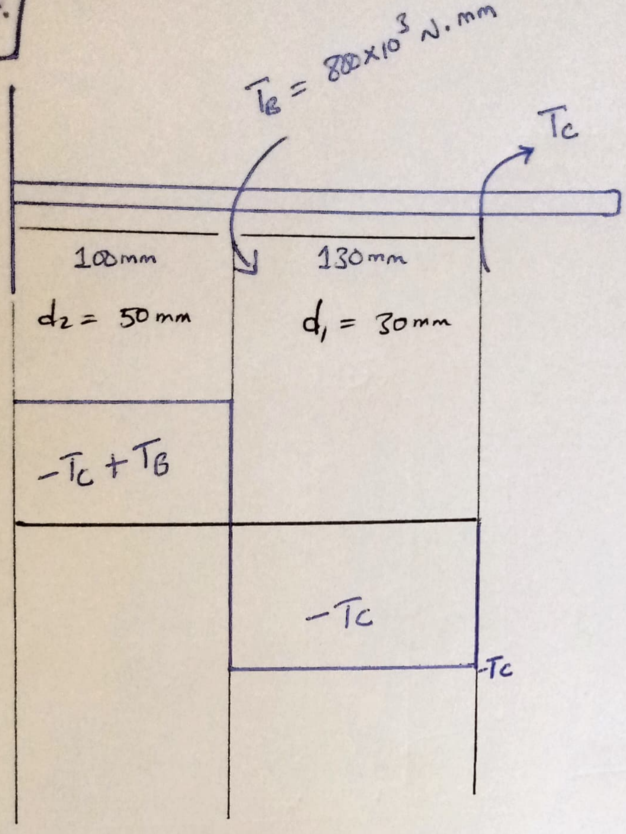
$\sigma_{bottom} = \frac{Mc}{I}$

$= \frac{19{,}333{,}400\ N.mm \times 25mm}{512{,}500\ mm^4}$

$\sigma_{bottom} = 943.0926829$

$\sigma_{maximum\ Compression} = 943.09 MPa\ (C)$

[Q 4.]



Data

Shaft 1 (Steel)

$L_1 = 100$ mm

$D_1 = 50$ mm

$G = 76 \times 10^3$

Shaft 2 (Brass)

$L_1 = 130$ mm

$D_1 = 30$ mm

$G = 45 \times 10^3$

$$\phi = \frac{TL}{JG}$$

$$\phi_A = \phi_c + \phi_B$$

$$0 = \frac{T_c L}{JG} + \frac{T_B L}{JG}$$

$$0 = \frac{-T_c L}{JG} + \frac{(-T_c + T_B) L}{JG}$$

$$0 = \frac{-T_c \cdot 130 \times 32}{\pi \cdot (30)^4 \times (45 \times 10^3)} + \frac{(-T_c + T_B) \cdot 100 \times 32}{\pi \cdot (50)^4 \times (76 \times 10^3)}$$

$$0 = \frac{-T_c\, 4160}{1.145110522 \times 10^{11}} + \frac{-T_c\, 3200}{1.49225651 \times 10^{12}} + \frac{2,560 \times 10^6}{1.49225651 \times 10^{12}}$$

$$0 = -T_c\, 3.63 \times 10^{-8} - T_c\, 2.1444 \times 10^{-9} + 1.71552 \times 10^{-3}$$

$$\frac{-1.71552 \times 10^{-3}}{-3.8444 \times 10^{-8}} = \frac{-T_c\, 3.8444 \times 10^{-8}}{-3.8444 \times 10^{-8}}$$

$$T_c = 44,591.59 \text{ N.mm}$$

$$\therefore T_c = 44,591.60 \text{ N.mm}$$