The University of Zambia
School of Engineering
Department of Civil and Environmental Engineering

CEE 3211 – Mechanics of Materials Test (2023)

Instructions

Attempts all four questions. All Questions Carry equal marks

Duration: 2 hours

Q1. The assembly consists of two 15-mm-diameter aluminium rods AB and CD, a 25-mm-diameter aluminum rod EF, and a rigid bar AEC. With the loads applied as shown, determine the **overall displacement** of end **F** of rod EF. Take E_{al} = 70 GPa.

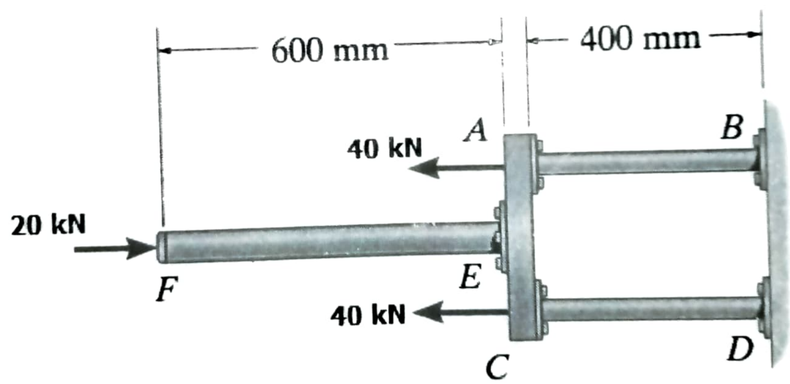


Fig Q1

Q2 A composite cylindrical rod, ABCD consists of bar 1, Bronze (E = 101 GPa) and Bar 2, Cast Iron (E = 84 GPa) fixed at both ends as shown in Figure Q2. The bar has a point load P = 50 kN applied at the collar as shown. The thermal coefficient of expansion for Bronze and Cast Iron coefficient as 17×10^{-6}/°C and 10.8×10^{-6}/°C respectively. The composite rod is subjected to a temperature rise of 130°C. Assuming the rod is initially unstressed:

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

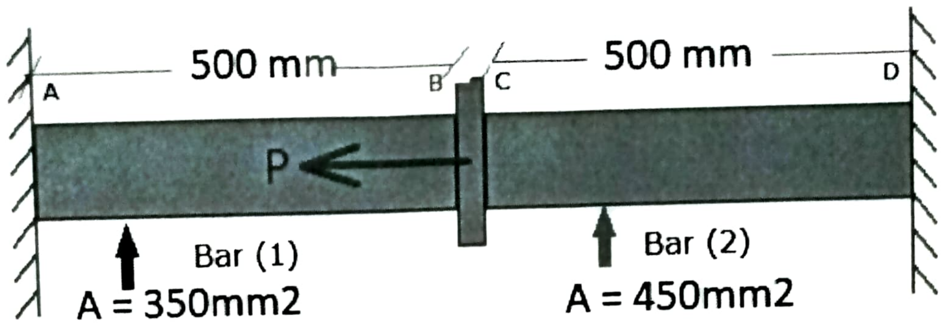


Fig Q2

Q3 A steel beam of 8 m in length has a T cross-section shown in Figure Q3. A positive bending moment M = 25 kN.m is applied to the beam. Calculate the **maximum compressive** and **tensile stresses**. Take E_{st} as 200 GPa.

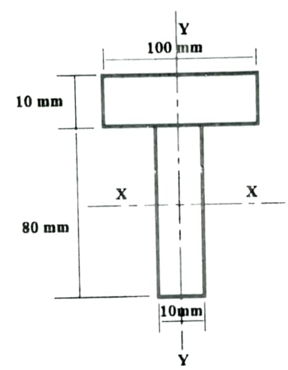


Fig Q3

Q4. A shaft ABCD shown in Fig Q4 is fixed at A and consists of 3 solid circular segments, each with a diameter of 50mm. The shaft is subjected to torques T1, T2, and T3 acting as shown in the figure. All three segments have the same length of 500 mm, but they are made of different materials. Shear Moduli for AB, BC and CD are 26GPa, 37GPa and 76GPa respectively. Calculate the following quantities:

(a) the **shear stress** in each segment
(b) the **angle of twist (in degrees)** at end D.

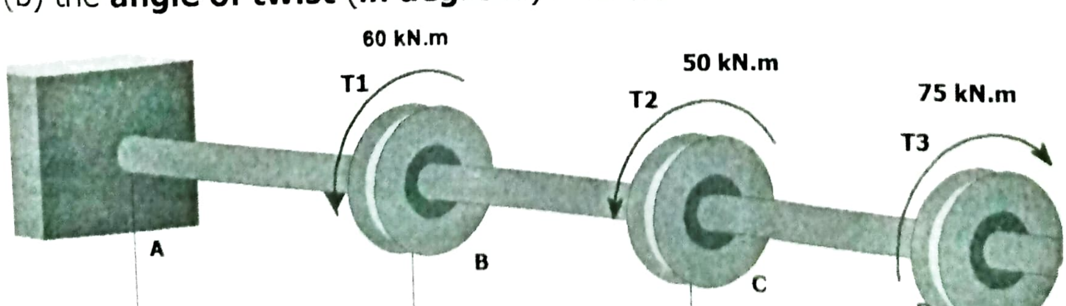


Fig Q4

THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

UNIVERSITY EXAMINATIONS

FINAL EXAMINATIONS

30th JUNE 2023

CEE 3211– MECHANICS OF MATERIALS

Candidates are advised to read the following instructions carefully

1. *This examination is a closed book*
2. *The time allowed is three (3) hours*
3. *Attempt ANY FIVE (5) questions* ***underlining your answers***
4. *All questions carry equal marks*
5. *This question paper has SIX printed pages including this cover*

Q1. Figure Q1 shows 3 solid cylindrical rods that are welded together to form the compound axial member. The member is rigidly fixed to a fixed support at A. Each rod has an elastic modulus of $E = 47$ GPa. Use the following values for the rod lengths and areas: $L_1 = 1{,}500$ mm, $L_2 = 1{,}800$ mm, $L_3 = 1{,}300$ mm, $A_1 = 300$ mm², $A_2 = 150$ mm², and $A_3 = 70$ mm². What magnitude of external load P is needed to displace end D a distance of 53 mm to the right?

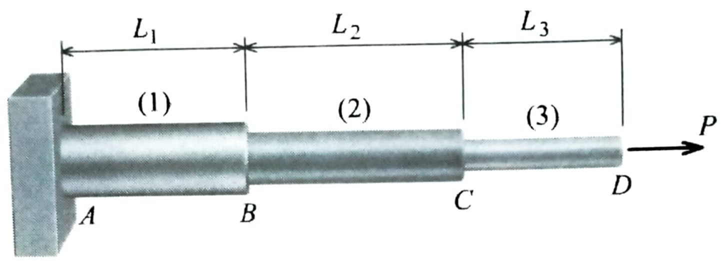


Figure Q1

[20 Marks]

Q2 At a temperature of 20°C, a 3mm gap exists between the ends of the two bars shown in Figure Q2. Bar (1) is a brass alloy [$E = 110$ GPa, $\alpha = 20 \times 10^{-6}$/°C] bar with a length of 600mm and a cross-section area of 45mm². Bar (2) is a bronze [$E = 103$ GPa, $\alpha = 17 \times 10^{-6}$/°C] bar with a length of 500mm and a cross-section area of 55mm². The supports at A and D are rigid. Determine:

a. the lowest temperature at which the two bars contact each other.
b. the normal stress in the two bars when the temperature rises to 270°C.

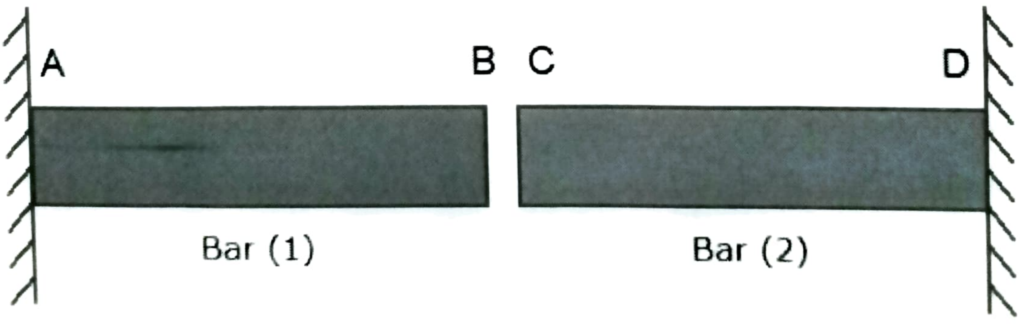


Figure Q2

[5+15 Marks]

Q3. Figure Q3 shows a beam with an inverted tee-shaped cross-section which is subjected to a **negative bending moment** of 50 kN-m. The dimensions for the section are shown in the figure provided. Determine:

a. The location of the centroid
b. The moment of inertia
c. The controlling section modulus
d. The bending stress at points A and B.
e. The maximum bending stress produced in the cross-section and state whether the stress is tension or compression.

{Dimensions are in millimetres}

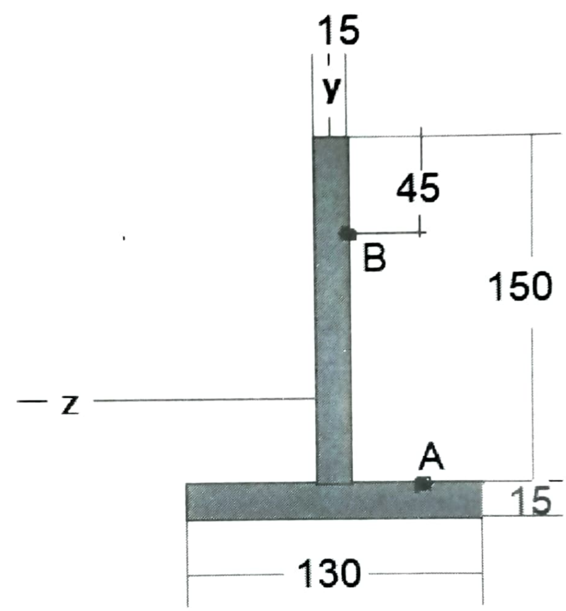


Figure Q3

[3+ 3+2+7+5 Marks]

Q4. A shaft ABCD shown in Fig Q4 is fixed at end support A and consists of 3 solid circular segments, each with a diameter of 50mm. The shaft is subjected to torques at points B, C and D with magnitude and direction as shown in the figure. All three segments have the same length of 500 mm, but they are made of different materials. Shear Moduli for AB, BC and CD are 26GPa, 37GPa and 76GPa respectively.

a. Plot the torque diagram for the shaft
b. Calculate the shear stress in each segment
c. Calculate the angle of twist (**in degrees**) at end D.

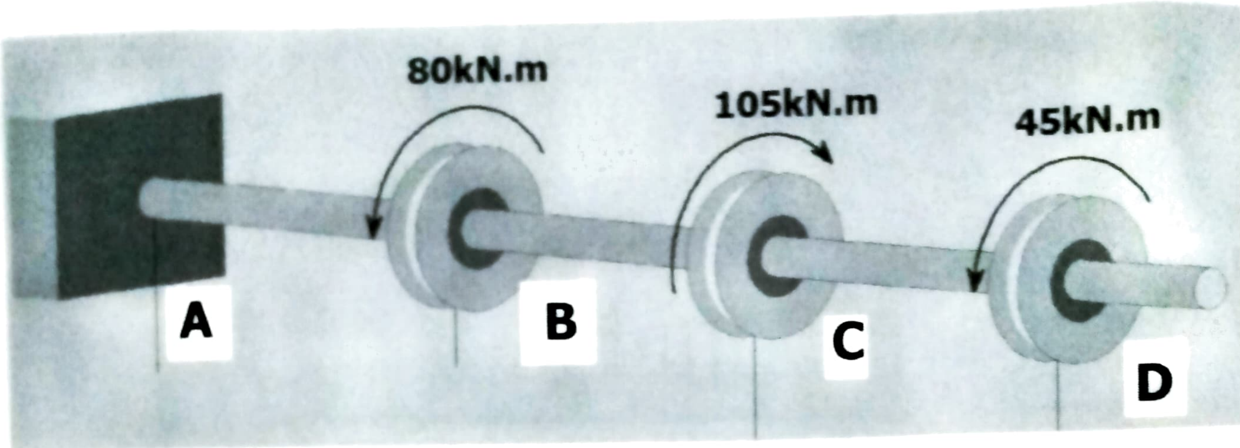


Figure Q4

[4+8+8 Marks]

Q5. A column of 7 m in length has an I cross-section as shown in Figure *Q5*. Assume Young's Modulus to be 205 GPa

(i) Calculate the least radius of gyration.

(ii) Calculate the slenderness ratio if the column end conditions are considered **fixed** on both ends.

(iii) Calculate the Euler buckling load of the column to which the theory applies.

(iv) If the column material has a compressive stress of 485 N/mm^2, determine the shortest length of this column.

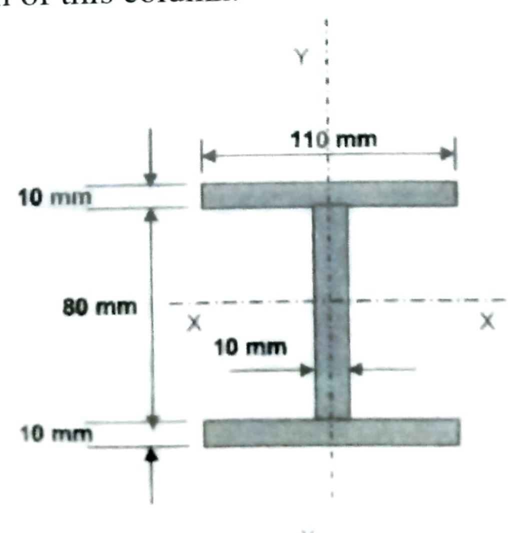


Figure Q5

[5+5+5+5 Marks]

Q6. A steel propped cantilever beam shown in Figure Q6 is loaded with a triangular distributed load with $w_0 = 120$ kN/m. Take $L = 5$ m and assume EI to be constant.

a. Calculate the reaction forces at supports A and B.
b. Calculate the bending Moment at support B

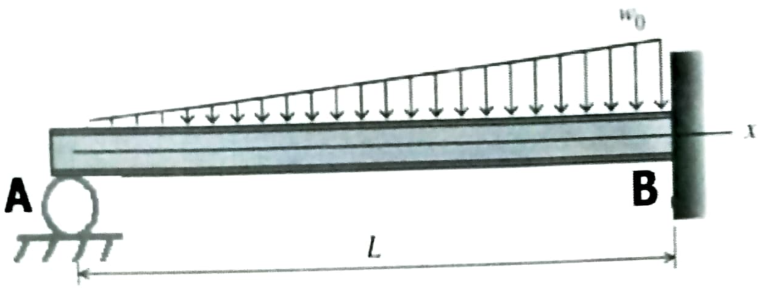


Figure Q6

[14+8 Marks]

Q7. A 3-member truss shown in Figure Q7 carries a horizontal load of 125 kN at joint C. The cross-sectional area of all members is 225 mm^2 and E = 205GPa. Determine the vertical displacement of **joint C** using the **method of virtual work.** Take the lengths AB and BC as 4m and 3m respectively

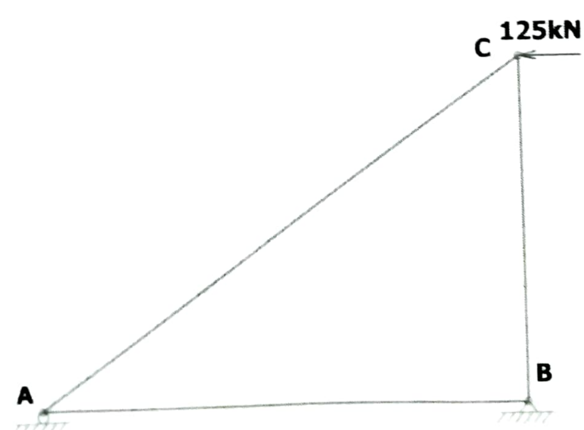
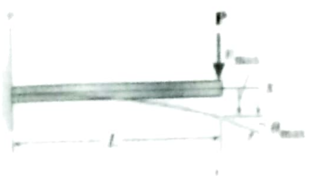
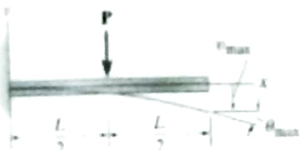
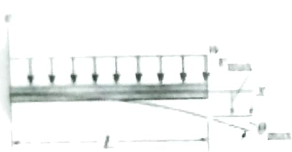
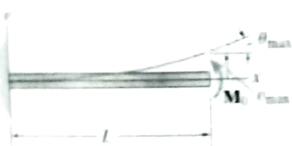
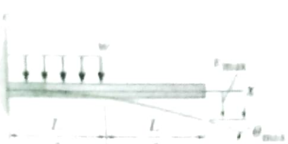
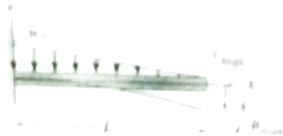


Figure Q7

[20 Marks]

APPENDICES

Cantilevered Beam Slopes and Deflections

Beam	Slope	Deflection	Elastic Curve
	$\theta_{max} = \frac{-PL^2}{2EI}$	$v_{max} = \frac{-PL^3}{3EI}$	$v = \frac{-Px^2}{6EI}(3L - x)$
	$\theta_{max} = \frac{-PL^2}{8EI}$	$v_{max} = \frac{-5PL^3}{48EI}$	$v = \frac{-Px^2}{12EI}(3L - 2x) \quad 0 \le x \le L/2$ $v = \frac{-PL^2}{48EI}(6x - L) \quad L/2 \le x \le L$
	$\theta_{max} = \frac{-wL^3}{6EI}$	$v_{max} = \frac{-wL^4}{8EI}$	$v = \frac{-wx^2}{24EI}(x^2 - 4Lx + 6L^2)$
	$\theta_{max} = \frac{M_0 L}{EI}$	$v_{max} = \frac{M_0 L^2}{2EI}$	$v = \frac{M_0 x^2}{2EI}$
	$\theta_{max} = \frac{-wL^3}{48EI}$	$v_{max} = \frac{-7wL^4}{384EI}$	$v = \frac{-wx^2}{24EI}(x^2 - 2Lx + \frac{3}{2}L^2)$ $0 \le x \le L/2$ $v = \frac{-wL^3}{384EI}(8x - L)$ $L/2 \le x \le L$
	$\theta_{max} = \frac{-w_0 L^3}{24EI}$	$v_{max} = \frac{-w_0 L^4}{30EI}$	$v = \frac{-w_0 x^2}{120EIL}(10L^3 - 10L^2 x + 5Lx^2 - x^3)$