Program: DTE (2nd Sem) Date: 14 May, 2024

Time: 10:00 am – 01:00 pm

(Group A - Morning)

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination	**Summer Semester: A.Y. 2022 - 2023**
Course Number: ME 4403	**Time : 03 Hours**
Course Title: Mechanics of Materials	**Full Marks : 150**

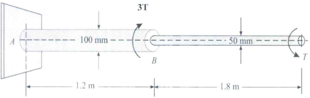
There are 06 (Six) Questions. Answer all of them.

Each question carries equal marks. Symbols have their usual meanings. Draw the free body diagram if required. The right column also indicates the course objective (CO) and Program Outcomes (PO) addressed by each question. Assume reasonable values for missing data.

1 **(a)** The stepped steel shaft shown in Figure below is subjected to a torque (T) at the free end, and a torque (3T) in the opposite direction at the junction of the two sizes. 12

CO2

What is the total angle of twist at the free end, if maximum shear stress in the shaft is limited to **70 MPa**? Assume the modulus of rigidity to be **84 GPa**. PO2

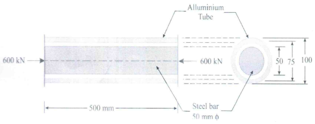


(b) A solid steel bar **500 mm** long and **50 mm** diameter is placed inside an aluminium tube **75 mm** inside diameter and **100 mm** outside diameter. The aluminium tube is 0.5mm longer than the steel bar. An axial load of **600 kN** is applied to the bar and cylinder through rigid plates as shown in Figure below. 13

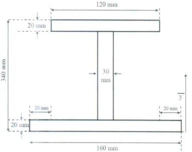
CO2

PO2

Find the stresses developed in the steel bar and aluminium tube. Assume E for steel as **200 GPa** and E for aluminium is **70 GPa**



2 An I-section girder is used as a simply supported beam over a span of **8** m. The cross section of the girder is shown in **Fig. 2(a).** And the loading condition is shown in **Fig. 2(b).** If modulus of elasticity is given as **E = 100 GPA.** **45** **CO3** **PO2**

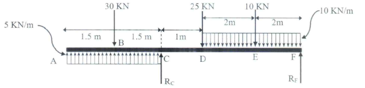


(i) Determine $\bar{y}$ and **I** (1st and 2nd moment of area) of the section

(ii) Draw **S.F.D** and **B.M.D** for the Beam

(iii) Use Macaulay's method to find **bending moment**, **slope** and **deflection** at **A, C, E**

(iv) Find M_{max} and maximum stress set-up (σ_{max}) in the Beam



3 (a) Write the difference between column and struts with example **5** **CO1** **PO1**

(b) Draw schematic diagrams of different end conditions in column with corresponding equivalent length equations. **5** **CO1** **PO1**

4 (a) A material is subjected to two mutually perpendicular direct stresses of **80 MN/m²** tensile and **50 MN/m²** compressive, together with a shear stress of **30 MN/m²**. The shear couple acting on planes carrying the **80 MN/m²** stress is clockwise in effect. Calculate **30** **CO4** **PO2**

(i) The magnitude and nature (angle) of the principal stresses.

(ii) The magnitude of the maximum shear stresses in the plane of the given stress system.

(iii) The direction of the planes on which these stresses act.

(iv) The magnitude of the normal and shear stress on a plane inclined at 20° counterclockwise to the plane on which the **50** MN/m² stress acts.

Confirm your answer by means of a drawing Mohr's stress circle diagram of the problem

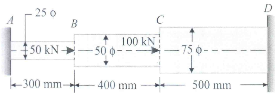
5 (a) Derive the following relation of bending moment equation with proper assumptions and schematic diagram. **13 CO1 PO1**

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

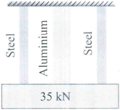
(b) Write the relationship equations between deflection, slope, bending moment, shear force and load distribution **7 CO1 PO1**

6 (a) A circular steel bar ABCD, rigidly fixed at A and D is subjected to axial loads of **50 kN** and **100 kN** at B and C as shown in the following figure. **12 CO2 PO2**

Find the loads shared by each part of the bar and displacements of points B and C. Take E for the steel as **200 GPa**.



(b) A block showing in the following figure, weighing **35 kN** is supported by three wires. The outer two wires are of steel and have an area of 100 mm^2 each, whereas the middle wire of aluminum and has an area of 200 mm^2 .If the elasticity modulus of steel and aluminum are **200 GPa** and **80 GPa** respectively, then calculate the stresses in the aluminum and steel wires. **8 CO2 PO2**



Related Equations:

The stresses on oblique planes owing to a complex stress system are:

$$\text{normal stress} = \tfrac{1}{2}(\sigma_x + \sigma_y) + \tfrac{1}{2}(\sigma_x - \sigma_y)\cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\text{shear stress} = \tfrac{1}{2}(\sigma_x - \sigma_y) \sin 2\theta - \tau_{xy} \cos 2\theta$$

The *principal stresses* (i.e. the maximum and minimum direct stresses) are then

$$\sigma_1 = \tfrac{1}{2}(\sigma_x + \sigma_y) + \tfrac{1}{2}\sqrt{[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2]}$$

$$\sigma_2 = \tfrac{1}{2}(\sigma_x + \sigma_y) - \tfrac{1}{2}\sqrt{[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2]}$$

and these occur on planes at an angle θ to the plane on which σ_x acts, given by either

$$\tan 2\theta = \frac{2\tau_{xy}}{(\sigma_x - \sigma_y)} \quad \text{or} \quad \tan\theta = \frac{\sigma_p - \sigma_x}{\tau_{xy}}$$

where $\sigma_p = \sigma_1$, or σ_2, the planes being termed *principal planes*. The principal planes are always at 90° to each other, and the *planes of maximum shear* are then located at 45° to them.

The *maximum shear stress* is

$$\tau_{max} = \tfrac{1}{2}\sqrt{[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2]} = \tfrac{1}{2}(\sigma_1 - \sigma_2)$$