UNIVERSITY OF NAIROBI

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FME 502- SOLID MECHANIS II

TUTORIAL SHEET NO 1.

1. A thin-walled box tube has the cross- section shown in Fig. Q.1. The tube is subjected to a pure torque T of 11 kN-m. Determine the shear stresses on the walls of the cross- section and sketch the same by means of arrows showing the directions of the shear stresses.

   (Ans. $\tau_{AB} = \tau_{BC} = 98$ MN/m^2, $\tau_{CA} = 32$ MN/m^2, $\tau_{CD} = \tau_{DA} = 132$ MN/m^2)

2. Fig. Q.2 shows a double-celled tubular cross-section of the dimensions as shown. If the angle of twist is limited to 5° per meter length, determine the maximum torque that can be applied to the tube. Take the modulus of rigidity for the material to be 80 GN/m^2.

   (Ans. $T_{max} = 57.55$ kN-m)

3. A thin-walled tube is made from a double-celled tubular cross-section and subjected to a pure torque of 200 kN-m. The left segment of the cross-section is rectangular-semi-elliptical and the right hand segment is rectangular-dished-semi-circular with dimensions as shown in Fig. Q.3. The tube is made from a material whose modulus of rigidity is 100 GN/m^2. Determine the shear stress in each segment of the cross-section and the angle of twist per unit length of the tube.

   (Ans. $\tau_{ABC} = 147.47$ MN/m^2, $\tau_{CDA} = 107.74$ MN/m^2, $\tau_{CA} = 90.65$ MN/m^2, $\theta/L = 0.0121$ rad/m)

4. A thin rectangular strip of length L, width b, and thickness t, (with b>>t), is subjected to a pure torque T. Derive expressions that may be used to estimate the maximum torque, T_{max}, that the strip may take and the maximum shear stress, τ_{max}, in the strip for a given angle of twist, θ, for the strip. Assume that the strip material has a shear modulus G.

   A thin-walled cross-section of dimensions as shown in Fig. Q.4 is subjected to a pure torque T. If the angle of twist for the section should not exceed 8°, determine the maximum torque that the cross-section can take, and the largest value of the maximum shear stress in the section under the maximum applied torque. Take the shear modulus of the material to be $100 GN/m^2$.

(Ans. T_{max} = 7.64 kN-m, τ_{max} = 209.44 MN/m^2)

5. A beam column of length L and constant flexural stiffness EI has both ends pinned and subjected to axial compressive loads, P, at the ends and transverse load W at mid-span. Show that the deflection curve has the equation given by:

$$y = \frac{W}{2\alpha P} \sec \frac{\alpha L}{2} \sin \alpha x \quad \frac{W x}{2P}$$

where $\alpha^2 = P/EI$ and x is measured along the length of the column from the pinned end.
If for a particular column L = 2.5 m, P = 10 kN, W = 2.5 kN and the column is of a circular cross- section of diameter 60 mm, determine the maximum central deflection, δ_{max}, the maximum bending moment, M_{max}, and the maximum compressive stress, σ_c, in the column. Take the Young's modulus for steel to be 210 GN/m^2, and neglect the weight of the column.

(Ans. δ_{max} = 6.39 mm, M_{max} = 1.626 kN-m, σ_c = 80.23 MN/m^2)

6.

a) Explain briefly how the Euler's crippling load. P_E, may be determined in the laboratory for:
   i) An ideal strut with different end constraints, and
   j) A pin-ended strut with an initial small deflection which may be due lateral loading.

b) A strut of length 2.75 m and of rectangular cross- section, width 150 mm, and depth 100 mm, is pinned at both ends. It is loaded with axial compressive loads, P, at both ends, a lateral central load, F, and a uniformly distributed load, ω per unit length, over its entire length. The various loads are proportioned such that F = 2P, ωL = 3P/2, and P = $P_E/5$, where P_E is the Euler's crippling load for a strut loaded axially at its pinned ends. Using the engineering rigorous method for analysis of struts, determine, in absolute values:
   i) The maximum deflection, maximum bending moment, and the maximum compressive stress assuming no interaction between axial and lateral forces,
   j) The maximum deflection, the maximum bending moment, and the maximum compressive stress assuming complete interaction between axial and lateral forces, and
   k) The percentage differences between the corresponding values calculated in i) and j) above.

Take the Young's modulus for the strut material to be 205 Gn/m^2.

(Ans. i) 332.2 mm, 1.264 MN-m, 5100 MN/m^2; j) 415.25 mm, 1.542 MN-m, 6213 MN/m^2; k) 20%, 18.03%, 17.90%)

7. A beam column with pinned ends is subjected to axial compressive loads, P, at the ends and a uniformly distributed load ω per unit length over the whole length. The loads are proportioned such that $\omega = P/L$ and $P = P_E/4$, where P_E is the Euler's crippling load for the column with pinned ends. For a symmetrical and uniform cross-section of depth d, using the approximate rigorous engineering method for analysis of struts, derive expressions for:
   a) The maximum compressive stress, σ_c, due to bending only, without interaction between axial and transverse loading,
   b) The maximum compressive stress, σ, due to bending only but with complete interaction between axial and transverse loading.
   c) Express $\sigma = C \cdot \sigma_c$, where C is a constant. Determine C.

(Ans. a) $\sigma_c = 0.0625 \dfrac{PLd}{I}$, b) $\sigma = 0.08392 \dfrac{PLd}{I}$, c) C = 1.342)

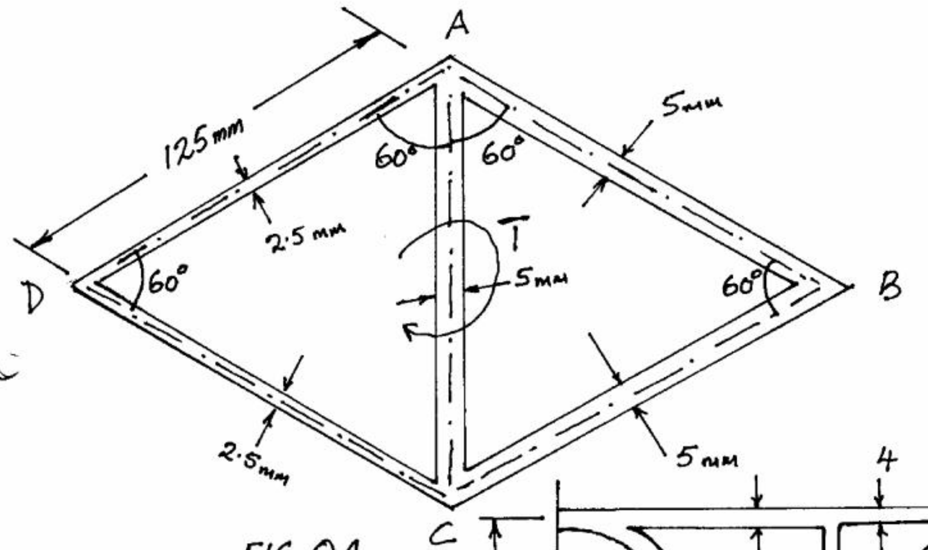

FIG. Q.1.

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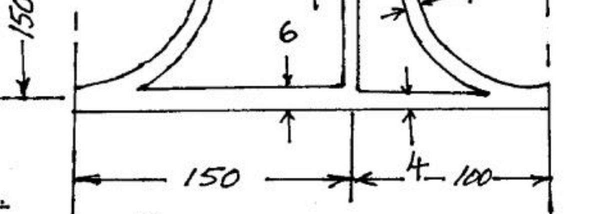

Units: mm

FIG. Q.2.

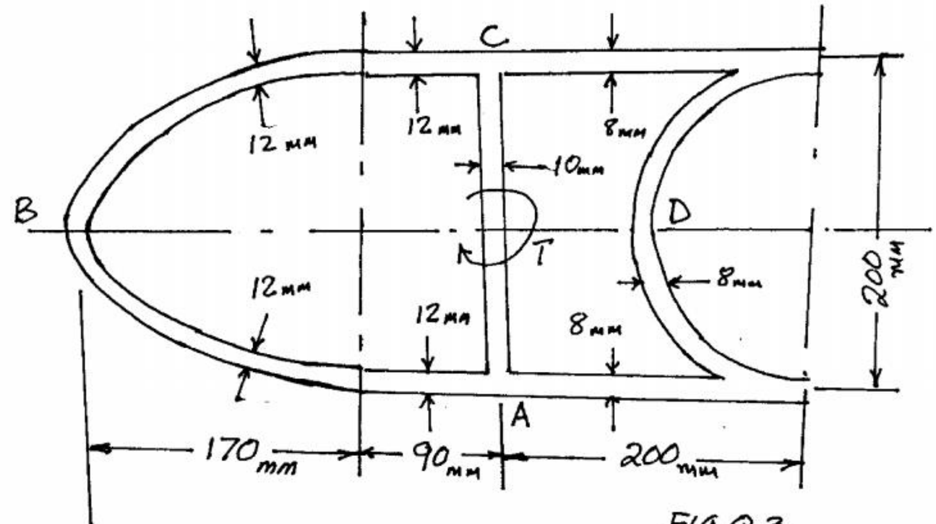

FIG. Q.3.

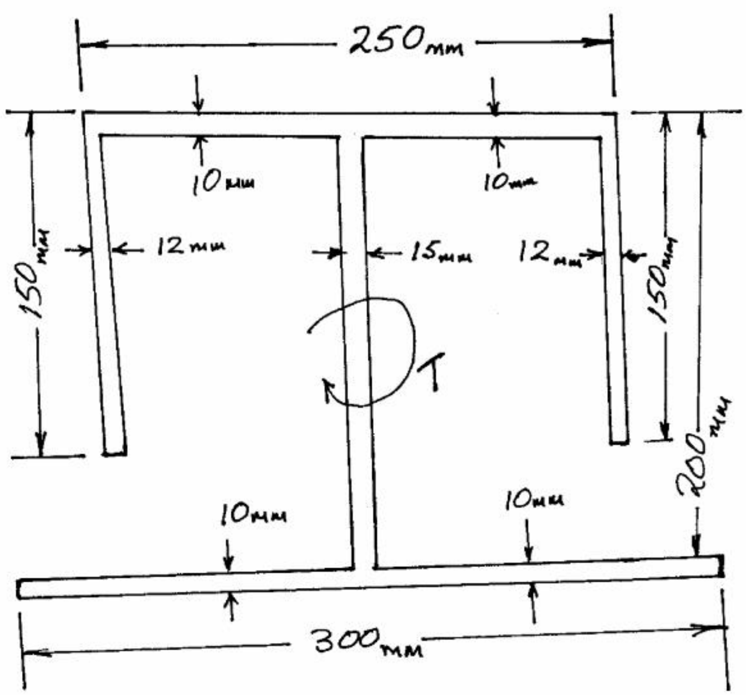

FIG. Q.4.

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