00039

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX5302 Strength of Materials II**
Academic Year	: 2021/22
Date	:06 February 2023
Time	: 9.30 am – 12.30 pm
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Six (6)** questions in **five (5)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. This is a Closed Book Test (CBT).
5. Answers should be in clear handwriting.
6. Do not use Red colour pen

Q1 (a) Write down the general equations for radial and hoop stresses for thick cylinders identifying all the notations. (2 marks)

(b) A thick cylinder having radii 0.06m and 0.12m is subjected to an external pressure, P_o. Figure Q 1 shows the plot of stresses in the cylinder wall. The maximum hoop stress in the cylinder is 25 MPa.

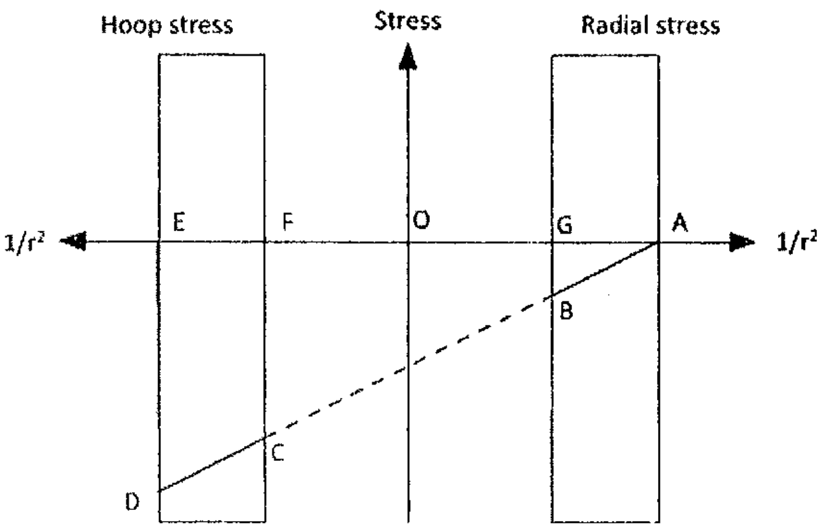

Figure Q1

(a) Find the following

(i) Value of the applied external pressure (5 marks)

(ii) Hoop stress at the outer radii of the cylinder (5 marks)

(b) The cylinder is subjected to an internal pressure P_i, while already applied external pressure (P_o) is maintained. (8 marks)

What is the value of internal pressure that will reduce the maximum hoop stress to 50% of initial value?

Q2 (a) A compound cylinder has been made of the same material, with inner and outer radii 0.06 m and 0.1 m respectively, and with interface radius of 0.08m. The interface pressure is 20MPa. Modulus of Elasticity of cylinder material is 100 GPa.

Find the following.

(i) Hoop stresses at the interface for both cylinders (5 marks)

(ii) Total interference of the two cylinders (5 marks)

(b) The compound cylinder in (a) is subjected to an internal pressure that will make the hoop stress at the **outer surface** of the **inner cylinder** is zero.

(i) Sketch the radial stress and the hoop stress against $1/r^2$ before and after the pressure is applied on the same coordinate system. (5 marks)

(ii) Find the applied internal pressure to the compound cylinder. (5 marks)

Hint: Consider the compound cylinder as a single cylinder when internal pressure is applied.

Q3 (a) A rectangular steel tube has dimensions and wall thicknesses as shown in Figure Q3

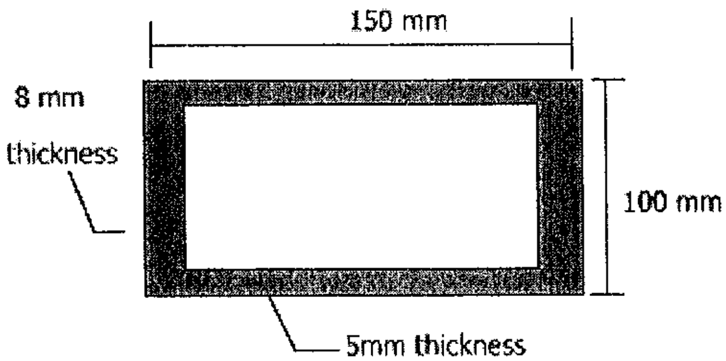

Figure Q3

Find the following.

(i) Maximum axial torque that can be carried by the tube if the maximum shear stress is limited to 10 MPa. (4 marks)

(ii) Angel of twist per unit length of the tube, if the modules of rigidity of steel is 75 GPa. (4 marks)

(iii) Diameter of a thin walled tube that can carry the same torque found in (i) with a wall thickness of 5mm. (4 marks)

You may use the following equations with usual notation applicable for thin-walled tubes in torsion.

$$\tau = \frac{T}{2At} \qquad \theta = \frac{TL}{4GA^2}\frac{z}{t}$$

(b) A shaft having a rectangular solid section of 150 mm x 100 mm carries an axial torque.

Find the following.

(i) Torque that causes a maximum shear stress of 10MPa (4 marks)

(ii) Corresponding angle of twist per unit length of the shaft if the modulus of rigidity of the material is 75 GPa. (4 marks)

You may use the following information with usual notation.

$$\tau_{max} = \frac{T}{k_1 db^2}, \quad \frac{\theta}{L} = \frac{T}{k_2 db^3 G}$$

d/b	1.0	1.5	1.75	2.0	2.5	3.0	4.0	6.0	8.0	10.0	∞
k_1	0.208	0.231	0.239	0.246	0.258	0.267	0.282	0.299	0.307	0.313	0.333
k_2	0.141	0.196	0.214	0.229	0.249	0.263	0.281	0.299	0.307	0.313	0.333

Q4 (a) Explain the occurrence of deformation beyond elastic limit in beams and its significance in component design. (2 marks)

(b) What is meant by "Shape Factor" related to plastic deformation? (3 marks)

(c) A simply supported beam of 2 m length having square cross section, carries a concentrated load of W at its mid span. The elastic limit of the beam material is 400 MPa.

Calculate the following.

(i) Beam cross sectional dimensions, when the bending stress reaches elastic limit with ***W*** = 10 kN (5 marks)

(ii) Value of ***W*** when the plastic hinge is created at the point of maximum bending moment with the beam sectional dimensions found in (i) above. (5 marks)

(iii) Distance to the point, from one end of the beam, where plastic yielding has taken place to a half depth on either side to the neutral axis with the load ***W*** found in (ii) above. (5 marks)

Q5 A cantilever beam having a T – Section with dimensions as shown in Figure Q5 is subjected to a point load of 3 KN acting at an angle of 20° to the vertical at the free end. The length of the cantilever is 1 m.

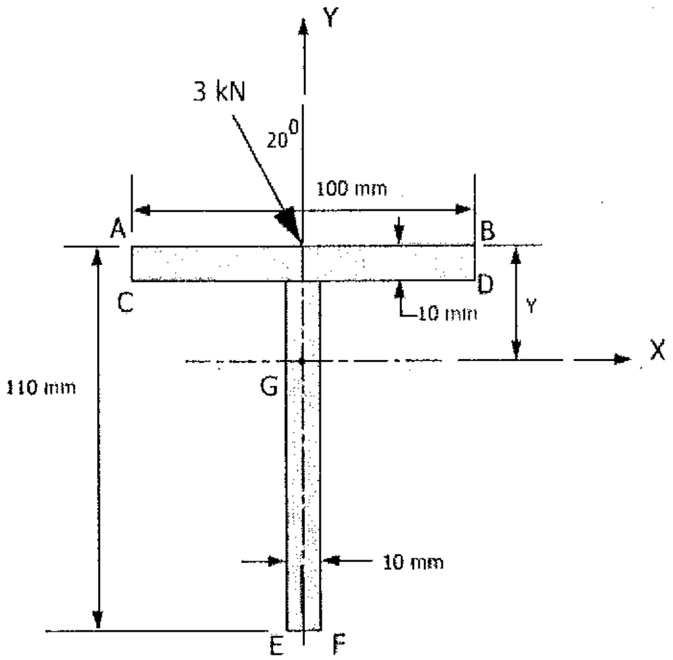

Figure Q5

Find the following

(i) Distance (Y) to the center of mass (G) from the top of the 'T' section. (5 marks)

(ii) Second Moment of Area about X and Y axes going through the center of mass (G). (5 marks)

(iii) Maximum bending stress of the section. (5 marks)

(iv) Axial moment subjected by the cantilever (5 marks)

Q6 (a) Derive an expression for the coordinate transformation matrix for $X_i = (X_1, X_2, X_3)$ coordinate system with respect to the $X_i' = (X_1', X_2', X_3')$ coordinate system (see Figure Q6). (7 marks)

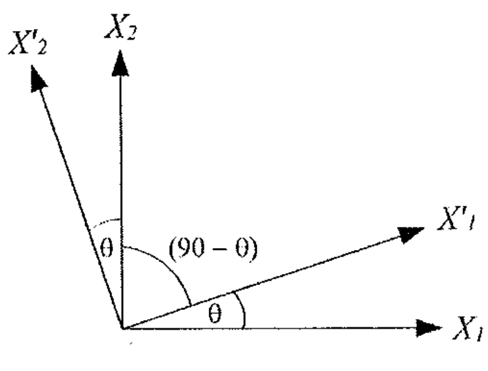

Figure Q6

(b) The stress σ at a point within a body is given in terms of the $X_i = (X_1, X_2, X_3)$ coordinate system as below. (3 marks)

$$\sigma = \begin{bmatrix} 2 & 3 & 4 \\ 1 & 3 & -5 \\ 2 & -5 & 0 \end{bmatrix} \text{MPa}$$

Determine the stresses with respect to the $X_i' = (X_1', X_2', X_3')$ coordinate system, if the transformation matrix is given as below.

$$[T] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & \frac{1}{2} \\ 0 & -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix}$$

(c) The stress state at a specific point within a machine element is represented by the following stress tensor. (3 marks)

$$\sigma = \begin{bmatrix} 9 & 2 & 0 \\ 2 & 10 & 0 \\ 0 & 0 & 3 \end{bmatrix} \text{MPa}$$

(i) Calculate the first invariant of this stress tensor. (3 marks)

(ii) Calculate the principal stresses associated with this stress tensor. (4 marks)