MECHANICS OF SOLIDS

***Time**: Three Hours*

***Maximum Marks**: 100*

Answer five questions, taking ANY TWO from Group A, any two from Group B and all from Group C.

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (a) Define the following (i) proportionality limit (ii) elastic limit (iii) yield point (iv) ultimate stress (v) rupture strength. 8

   (b) What is creep? Draw a typical creep curve and label its important areas. At what temperature does creep become significant? 6

   (c) What is true strain? How is it different from engineering strain? Obtain true strain in terms of engineering strain. 6

2. (a) Estimate (i) Young's modulus of elasticity (ii) yield point (iii) ultimate stress (nominal) (iv) ultimate stress (actual) (v) percentage elongation (vi) percentage reduction of area from the following data on tensile test of a mild steel specimen of dia 25 mm and length 300 mm: 8

   Extension under a load of 10 kN = 0.03 mm

   Load at yield point = 130 kN

   Load at failure = 212 kN

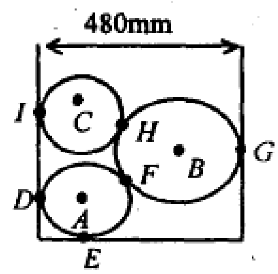
   Length of specimen at failure = 390 mm

   Neck diameter = 16.75 mm

   (b) Draw dimensional sketch of specimens used for Izod and Charpy tests. Explain the two tests. 6

   (c) Write the expressions for modulus of rigidity (G) and bulk modulus (K) in terms of Young's modulus of elasticity (E) and Poisson's ratio (μ). Establish 6 the relation between E, K and G.

3. (a) Three cylinders *A*, *B*, *C* of weights 100N, 200N, 300 N and radii 100 mm, 200 mm, 150 mm are placed in a rectangular ditch. Neglecting friction, determine reactions at various contact points. 8



(b) A mild steel bar, 6 m long, is 5 cm in diameter for 3 m of its length and 2.5 cm in diameter for the remaining length. The bar is in tension and the stress on the smallest section is 112 MPa. Find the total elongation of the bar and the change in diameter at the smallest section. Given: E = 200 GPa and Poisson's ratio = 0.15. 6

(c) Two rods A and B of equal free length hang vertically 60 cm apart and support a rigid bar horizontally. The bar remains horizontal when carrying a load of 5000 kg at 20 cm from rod A . If the stress in B is 50 N/mm^2, find the stress in rod A and the areas of A and B. Take E_A - 200,000 N/mm^2 and E_B = 90,000 N/mm^2. 6

4. (a) The principal stresses at a point in a bar are 200 N/mm^2 (tensile) and 100 N/mm^2 (compressive). Determine the resultant stress in magnitude and direction on a plane inclined at 60^0 to the axis of the major principal stress and also the maximum shear stress in the material at the point. 6

(b) A state of stress in a piece of elastic material is given by 6

$$\sigma_x = 800\,MPa$$
$$\sigma_y = -600\,MPa$$
$$\tau_{xy} = \pm 500\,MPa$$

Find the (i) principal stresses and the position of the planes on which they act and (ii) position of the planes on which there is no normal stress. Solve the problem analytically.

(c) Obtain relationship between shear force and bending moment. Define the 8 following in case of a loaded beam :

(i) Shear force diagram

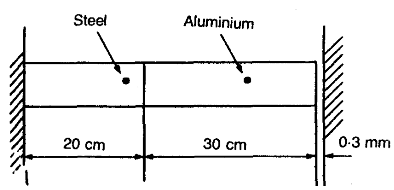
(ii) Bending moment diagram

(iii) Axial force diagram

(iv) Point of contraflexure.

Group B

5. (a) Determine the increase in temperature that will cause a compressive stress of 36 MPa in the composite rod shown in figure. Take E_s = 207 GPa, E_a = 73 GPa, $\alpha_s = 20.9 \times 10^{-6}\ /^0C$ and $\alpha_a = 23.6 \times 10^{-6}\ /^0C$. 8



(b) A steel bar, 4 cm in diameter and 5 m long, is heated through 60^0 C with ends clamped before heating. Estimate the thrust exerted by the steel bar on the clamps. Given: E = 210GPa and coefficient of thermal expansion, $\alpha = 11 \times 10^{-6}$ per °C. If the clamps have yielded by 0.05 cm, what would then be the thrust exerted? 6

(c) Give a derivation of the flexure formula for pure bending of a beam given below: 6

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

What is section modulus?

6. (a) Prove that the ratio of depth to width to the strongest beam that can be cut from a circular log of diameter *'d'* is $\sqrt{2}$. Hence, calculate the depth and width of the strongest beam that can be cut of a cylindrical log of wood whose diameter is 200 mm. 8

(b) Derive the relationship 6

$$\frac{T}{I} = \frac{G\theta}{L} = \frac{\tau}{r}$$

where T = torque applied, I = polar moment of inertia, G = modulus of rigidity, θ = angle of twist, L = length of shaft, x, τ = shearing stress and r =

radius of shaft.

(c) Compare the weighs of equal lengths of hollow and solid shafts to transmit a given torque for the same maximum shear stress if the inside diameter is 2/3 of the outside. 6

7. (a) Derive the expressions for hoop and longitudinal stresses induced in a thin cylindrical shell of internal diameter d and wall thickness t subjected to an internal fluid pressure p. Also, find change in volume. 8

(b) A thin cylinder and a thin spherical shell having the same diameter to wall thickness ratio are subjected to same internal pressure. Determine the ratio of their volumetric strains. Take Poisson's ratio as 0.25. 6

(c) A flat disc made up of steel, having a diameter of 1.2 m, rotates at a speed of 2700 rpm. Determine the intensities of radial and hoop stresses at. the external fibre. Take p =7.80 x 10^3 kg/m^3 and $\nu = 0.292$. 6

8. (a) Derive the expression for the deflection for a closed-coiled helical spring subjected to an axial load W, mean radius of the spring R, number of coils n, diameter of the wire of the spring is d and the shear modulus is G. 8

(b) What is strain energy? Show that the strain energy per unit volume is $\sigma^2/2E$. 6

(c) Prove that the maximum stress induced in a body due to suddenly applied load is twice the stress induced when the same load is applied gradually. 6

Group C

9. Choose the *correct* answer for the following: 20

(i) If the Poisson's ratio is 0.25, the ratio of Young's modulus to modulus of rigidity is

(a) 3.0

(b) 1.5

(c) 2.5

(d) 3.5

(ii) The radius of Mohr's circle is equal to

(a) half of the sum of the two principal stresses

(b) half of the difference of two principal stresses

(c) sum of the two principal stresses

(iii) In an experiment, it is found that the bulk modulus of a material is equal to its shear modulus. The Poisson's ratio is

(a) 0.125

(b) 0.250

(c) 0.375

(d) 0.500

(iv) Two identical shafts of diameters d_1 and d_2 are subjected to a torque T. The ratio of the strain energies stored will be

(a) $(d_1 / d_2)^4$

(b) $(d_1 / d_2)^2$

(c) $(d_2 / d_1)^2$

(d) $(d_2 / d_1)^4$

(v) If a circular shaft is subjected to a torque T and a bending moment M. the ratio of the maximum bending stress to the maximum shear stress is given by

(a) 2M/T

(b) M/T

(c) 2T/M

(vi) A thin cylindrical shell of internal diameter D and thickness t is subjected to internal pressure p, the change in diameter is given by

(a) $\frac{pD^2}{4tE}(2-\nu)$

(b) $\frac{pD^2}{4tE}(1-2\nu)$

(c) $\frac{pD^2}{2tE}(1-2\nu)$

(d) $\frac{pD^2}{2tE}(2-\nu)$

(vii) A rectangular beam is cut out of a cylinder log of diameter D. The depth of the strongest beam will be

(a) $\sqrt{\frac{1}{2}}D$

(b) $\sqrt{\frac{2}{3}}D$

(c) $\sqrt{\frac{5}{8}}D$

(d) $\sqrt{\frac{3}{4}}D$

(viii) For a helical closed-coiled spring when subjected to an axial compressive load, the stresses produced in the spring wire will be

(a) compressive stress and direct shear stress

(b) compressive stress and torsion shear stress

(c) direct shear stress and torsion shear stress

(d) bending stress and direct shear stress

(ix) In a thick cylinder subjected to internal pressure, the hoop stress through the thickness of the cylinder varies

(a) exponentially

(b) linearly

(c) parabolically

(d) cubically

(x) A beam with rectangular cross-section is simply supported and subjected to a concentrated load at the middle. The variation of shear stress through the thickness of the beam is

(a) constant

(b) linear

(c) quadratic

(d) cubic

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