M.E. MECHANICAL ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION – 2024
DESIGN OF STRUCTURAL ELEMENTS

Time: **Three hours** Full Marks: **100**

Different parts of a question must be answered together.
Provide sketches wherever applicable.
Missing Data, if any, may be reasonably assumed

Group – A [Answer Any **Five (5)**]

1. State the assumptions of Euler-Bernoulli Theory for beam bending and prove that the Euler-Bernoulli Theory is only valid where induced bending moment is constant or varies linearly along the longitudinal beam axis. [10]

2. Determine the ratio of maximum bending and shear deflections of a rectangular cross-section cantilever beam under uniform transverse loading. [10]

3. An initially curved beam (radius of curvature of the neutral axis - r_n) having uniform cross-section (area of cross-sectional - A) is subjected to a bending moment of M w.r.t. the centroidal axis. Prove that the induced bending ress, at a fiber located at a distance of y from the neutral axis is given by: [10]

$$\sigma_b = \frac{My}{Ae(r_n - y)}$$

[e is the eccentricity between the neutral axis and the centroidal axis]

4. Derive the moment-curvature relations for the deflected surface of a rectangular plate subjected to pure bending. [10]

5. State the boundary conditions corresponding (with mathematical expression) to free edge of a plate and describe the fallacy associated with it. Explain how this fallacy was resolved by Kirchoff. [02+02+06]

6. Write short notes on the following topics: [05×2]
   (*i*). Shear center
   (*ii*). Assumptions of classical plate theory

Group – B [Answer Any **Two (2)**]

8.(*a*). State and explain the energy principle of minimization of total potential energy. Write down its mathematical form and mention the energy functionals involved in the expression. Explain how the governing differential equations of the system can be obtained from the statement of minimization of total potential energy. [02+02+06]

8.(*b*). Describe what is meant by coordinate function, eigen function and admissible function. In this relation, discuss about different types of boundary conditions. [03+02]

8.(*c*). A long slender beam with uniform cross-section has clamped boundary conditions at its two ends and it is subjected to a concentrated load at mid-point of the beam. Determine an approximate expression for the transverse displacement field, $w(x)$, following energy method. [10]

[Turn over

9.(*a*). Under what conditions asymmetry in bending of beams may arise? A straight beam of asymmetric (but uniform) cross-section is subjected to a pure bending moment (M) at an arbitrary plane. The moment vector is not along any of the coordinate (x, y or z) directions. Derive an expression for the axial bending stress (σ_x) for the above-mentioned system. From the derived expression, determine the form of the formula if the cross-section is symmetric. [01+14+03]

9.(*b*). A cantilever beam of rectangular section is subjected to a load of 1.5 kN, which is inclined at an angle of 30° to the vertical. Determine the stress due to bending at point D (Figure Q9b) at the built-in-end? [07]

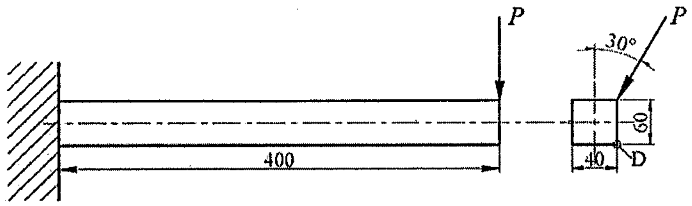

Figure Q9b

10.(*a*). A thin rectangular plate of dimension ($a \times b$) is simply-supported on its four edges and carries a distributed load $Q(x,y)$ on the surface of the plate. The expression for the distributed load is given as follows -

$$Q(x,y) = Q_0 \sin\left(\frac{\pi x}{a}\right) \sin\left(\frac{\pi y}{b}\right)$$

where, Q_0 is the intensity of the distributed load at the center of the plate. Determine an approximate expression for the transverse displacement field of the plate. [12]

10.(*b*). Derive von Karman's equations for large displacement analysis of rectangular plates. [13]

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