M.E. MECHANICAL ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION – 2025
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. Discuss the difference between stress distribution across the thickness of a straight and a curved beam. Write down the general expression for radius of curvature of the neutral axis and the shift in neutral axis from the centroidal axis of a curved beam. Derive the expression of the above-mentioned parameters for a trapezoidal cross-section. [03+02+05]

2. A straight beam with asymmetric but uniform cross-section is subjected to a pure bending moment in such a way that the moment vector is aligned along the z-axis. Comment on the orientation of the neutral plane of the beam under bending and determine an expression for it. Also derive an expression for the axial bending stress for the system. From the derived expression, determine the form of the formula if the cross-section is symmetric. [10]

3. Explain that the free surface of a beam is devoid of any shear stress. Prove that the maximum shear stress is 1.50 times the average shear stress in case of a beam with uniform rectangular cross-section. [03+07]

4. A perfectly flexible string with simply-supported boundary conditions at its two ends is subjected to uniformly distributed transverse load over the entire span. Determine an approximate expression for the transverse displacement field, $w(x)$, following energy method. Also determine an expression for axial tension (developed due to application of the transverse load) in terms of the loading and geometric parameters of the system. [10]

5. Derive the governing differential equation for a rectangular plate subjected to bending due to distributed transverse loading. [10]

6. 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. [10]

Group – B [Answer Any **Two (2)**]

7.(*a*). Explain what do you understand by shear center or center of flexure. Carry out a simplified approximate analysis, mentioning the simplifying assumptions, to find out an expression for the shear center of a thin channel section. Consider that the channel section is used for a cantilever beam which is loaded at the free end by a concentrated load acting along the centerline of the web. [05+10]

7.(*b*). Derive the Timoshenko beam equation in coupled form applying energy formulation and from the derived equations obtain the decoupled form of Timoshenko beam equation. Write down the boundary conditions associated with the derived governing differential equations. [10]

[Turn over

8.(*a*). State the assumptions of the classical plate theory (CPT) and mention their applicability and limitations. Mention some of the other plate theories and highlight the major differences with the CPT. [05+05+02]

8.(*b*). State the boundary conditions corresponding (with mathematical expression) to simply-supported, clamped and free edge of a plate. Explain the fallacy regarding the free end condition of a plate. Explain how this fallacy was resolved by Kirchoff. [05+02+06]

9. Write short notes on the following topics: [05×5]

(*i*). Advantages of energy formulation/method
(*ii*). Principle of minimization of total potential energy
(*iii*). Method of assumed solution
(*iv*). Validity of Euler-Bernoulli hypothesis
(*v*). Shear deformation of beams