# STRENGTH OF MATERIALS
## ENCE 151

**Lecture : 3** **Year : I**
**Tutorial : 1** **Part : II**
**Practical : 2/2**

**Course Objectives:**
The primary goal of the course is to build the fundamental understanding of students on geometric properties of sections, material behavior, stress-strain relations, flexure, torsion, buckling and failure types in the structural elements due to external loads and temperature variations. After completing this course, students should be able to develop competency on material behavior and their analysis due to external loadings and temperature change, evaluate geometric properties of complex geometric figures and analyze structural members under flexure, shear, torsion and buckling.

**1 Simple Stress and Strain (10 hours)**

1.1 Introduction to strength of materials
1.2 Deformable bodies, external forces, internal stresses and strains
1.3 Types of stresses: Normal stress, shear stress, bearing stress
1.4 Material behavior under axial loading: Stress-strain diagram for mild steel, yield stress, proportional limit, elastic limit, Hooke's law, Young's modulus of elasticity, strain hardening, ultimate stress/strength, ductility, toughness, elastic and inelastic strains, concept of factor of safety and allowable/permissible stress
1.5 Stress-strain behavior for ductile and brittle materials, proof stress
1.6 Fatigue and creep strength
1.7 Thermal stress and strain in simple, compound, composite and indeterminate bars
1.8 Lateral strains and Poisson's ratio
1.9 Shear deformation and shear angle; Hooke's law for shearing deformations, modulus of rigidity
1.10 Multi-axial loading and generalized Hooke's law
1.11 Definitions of isotropic, anisotropic and orthotropic materials
1.12 Volumetric stress-strain, bulk modulus
1.13 Relationships between elastic constants
1.14 Saint-Venant's principle and stress concentrations
1.15 Elongation of bars under axial loadings: Uniform and varying cross-sections, tapered sections, compound and composite bars
1.16 Use of compatibility equations for axially loaded indeterminate bars

## 2 Geometric Properties of Sections (5 hours)

- 2.1 Axes of symmetry
- 2.2 Centre of gravity of plane and built-up sections
- 2.3 Moment of inertia of standard and built-up sections
- 2.4 Parallel and perpendicular axis theorems
- 2.5 Polar moment of inertia
- 2.6 Radius of gyration
- 2.7 Product moment of inertia
- 2.8 Principal axes and principal moment of inertia
- 2.9 Mohr's circle for principle moment of inertia

## 3 Principal Stress Analysis in 2D Planes (5 hours)

- 3.1 Stresses in inclined plane: Normal stress under uniaxial loading, Normal and shear stress subjected to two mutually perpendicular planes
- 3.2 Principal planes and principal stresses
- 3.3 Relationships between normal and shear stresses
- 3.4 Maximum shear stresses
- 3.5 Mohr's circle diagram for principal stresses

## 4 Principal Strain Analysis (4 hours)

- 4.1 Plane strain: Normal and shear strains in inclined planes
- 4.2 Principal strains, maximum in-plane shear strains and their positions
- 4.3 Mohr's circle diagram for plane strain
- 4.4 Absolute maximum shear strain
- 4.5 Strain rosettes
- 4.6 Modes of failure for different materials
- 4.7 Introduction of failure theories

## 5 Thin Walled Vessels (3 hours)

- 5.1 Introduction and characteristics
- 5.2 Types of stresses and strains in cylindrical and spherical pressure vessels
- 5.3 Calculation of stresses and strains in pressure vessels

## 6 Torsion (5 hours)

- 6.1 Introduction to torsion
- 6.2 Stress-strain behavior in torsion
- 6.3 Derivation of torsion formula for a circular shaft
- 6.4 Torsional moments: Series and parallel combination of shafts and composite shaft
- 6.5 Torsional stress in shafts, torsional resilience
- 6.6 Comparison between solid and hollow shafts
- 6.7 Power transmitted by shafts

6.8 Statically indeterminate shafts
6.9 Introduction to non-circular shafts
6.10 Combined bending and torsion

**7 Theory of Flexure** **(8 hours)**

7.1 Introduction to flexure
7.2 Coplanar and pure bending
7.3 Derivation of bending equation
7.4 Distribution of bending stress across the different beam cross-sections
7.5 Analysis of beams for symmetric and composite sections
7.6 Shear equation, shear stress variation in rectangular, circular, I and T sections
7.7 Concept of slope and deflection in beams using double integration method: Simply supported and cantilever beams

**8 Column Theory** **(5 hours)**

8.1 Introduction: Buckling and stability of columns
8.2 Classification based on slenderness ratio
8.3 Effect of support conditions and effective length
8.4 Derivation of Euler's formula for different end conditions, limitations and applicability
8.5 Intermediate columns: Rankine's hypothesis
8.6 Introduction to uniaxial and biaxial eccentric loading, condition for no tension

**Tutorial** **(15 hours)**

1. Problems on stresses and strains on regular and irregular structural members due to external forces, self-weight and temperature change
2. Problems on geometrical properties of 2-D sections
3. Problems on principal stresses
4. Problems on principal strains
5. Problems on thin walled vessels
6. Problems on circular shafts due to torsion
7. Problems on flexure and deformation of beams
8. Problems on columns and compound stresses

**Practical** **(15 hours)**

1. Tensile test and stress-stress curve for mild steel bar, HYSD bar, timber
2. CG of simple plane figure
3. Simple bending test on timber, steel, aluminum beams: Deflection, flexural relations and MoI comparisons
4. Torsion test on simple shaft to determine modulus of rigidity
5. Test on column behavior and buckling

**Final Exam**

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

| Chapter | Hours | Mark distribution* |
|---|---|---|
| 1 | 10 | 13 |
| 2 | 5 | 7 |
| 3 | 5 | 7 |
| 4 | 4 | 5 |
| 5 | 3 | 4 |
| 6 | 5 | 7 |
| 7 | 8 | 10 |
| 8 | 5 | 7 |
| **Total** | **45** | **60** |

* There may be minor deviation in marks distribution.

**Reference**


1. Beer, F.P., Johnston, E.R. (2015). Mechanics of materials. Tata McGraw Hill.
2. Gere, J. M., Timoshenko, S. P. (2002). Mechanics of materials (Latest Edition). Nelson Thornes.
3. Rajput, R. K. (2018). A textbook of strength of materials. S. Chand and Company.
4. Vavikatti, S.S. (2013). Strength of materials. Vikas Publishing House.
5. Popov, E.P. (1978). Mechanics of materials (Latest Edition). Prentice Hall.
6. Pytel, A., Singer, F.L. (1998). Strength of materials (Latest Edition). Harper Collins.
7. Hibbeler, R.C. (2004). Statics and mechanics of materials. Prentice Hall.
8. Motra, G.B. (2021). A textbook of strength of materials. Heritage Publishers & Distributors.