

Program Name : Mechanical Engineering Program Group
Program Code : AE/ME/PG/PT/FG
Semester : Third
Course Title : Strength of Materials
Course Code : 22306

1. RATIONALE

Strength of Material is a core technology subject which aims at enabling the student to understand and analyze various types of loads, stresses and strains along with main causes of change in physical properties and failure of machine parts. All Mechanical Engineering components are subjected to different loadings and behave in a specific way. The subject is pre-requisite for understanding principles of machine design and strengths of various materials used in industries. Understanding mechanical properties of materials will help in selecting the suitable materials for various engineering applications.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- Estimate stresses in structural members and mechanical properties of materials.

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

- Compute Moment of Inertia of symmetric and asymmetric structural sections.
- Estimate simple stresses in machine components.
- Perform test to evaluate mechanical properties according to India Standards.
- Compute shear force and bending moment and corresponding shear and bending stresses in beams subjected to point and uniformly distributed load.
- Estimate stresses in shafts under twisting moments.
- Estimate stresses in short member subjected to eccentric loading.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
L	T	P		Theory						Practical						
				Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
Max	Min	Max	Min		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min		
3	2	2	7	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: L-Lecture; T- Tutorial/Teacher Guided Theory Practice; P - Practical; C – Credit, ESE - End Semester Examination; PA - Project Assessment



5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.



Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Determine yield stress, ultimate stress and breaking stress of Mild Steel by conducting Tension test (part I) as per IS 432 (I)	II	02*



S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
2	Determine yield stress, ultimate stress and breaking stress of Mild Steel by conducting Tension test (Part II) as per IS432 (I)	II	02
3	Plot stress-strain diagram for Aluminium by conducting Tension test (Part I) as per IS 1608	II	02
4	Plot stress-strain diagram for Aluminium by conducting Tension test (Part II) as per IS 1608	II	02
5	Calculate compressive strength of Ductile such as Mild Steel (MS), Aluminium (Al), Brass (Br), Copper (Cu), using Compression testing machine as per IS 14858	II	02*
6	Calculate compressive strength of Brittle materials such as Cast Iron (CI), High Carbon steel using Compression testing machine as per IS 14858	II	02
7	Determine shear strength of various metals such as MS, Al, Br and Cu, (Any two metals) by Single Shear test as per IS 5242	II	02*
8	Determine shear strength of various metals such as MS, Al, Br and Cu, (Any two metals) by Double Shear test as per IS 5242	II	02
9	Evaluate toughness of Ductile and Brittle materials such as MS, Al, Br and Cu, by conducting Izod Impact test as per IS 1757	III	02*
10	Determine energy absorption capacity of Ductile and Brittle materials such as MS, Al, Br and Cu, by conducting Charpy Impact test as per IS 1598	III	02*
11	Draw Shear force and Bending moment diagrams of given loading using open source SF/BM simulation software.	IV	02*
12	Find flexural strength by conducting Bending Test on timber beam of Rectangular cross section with shorter side horizontally oriented as per IS 1708, IS 2408	IV	02
13	Find flexural strength by conducting Bending Test on timber beam of Rectangular cross section with shorter side vertically oriented as per IS 1708, IS 2408	IV	02
14	Determine modulus of rigidity by conducting Torsion Test on MS (Part I) as per IS 1717	V	02*
15	Determine modulus of rigidity by conducting Torsion Test on MS (Part II) as per IS 1717	V	02
16	Determination of Direct stress, Bending stress and Resultant stresses for a given practical approach	VI	02
	Total		32

Note

- A suggestive list of **PrOs** is given in the above table. More such PrOs can be added to attain the COs and competency. A judicious mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.
- The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:



S. No.	Performance Indicators	Weightage in %
a.	Awareness about significance of particular test	15
b.	Understanding working principle of machine	15
c.	Preparation of experimental set up	20
d.	Setting and operation	20
e.	Observations and recording	10
f.	Interpretation of result and conclusion	10
g.	Answer to sample questions	5
h.	Submission of report in time	5
Total		100

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

- a. Follow safety practices.
- b. Practice good housekeeping.
- c. Demonstrate working as a leader/a team member.
- d. Maintain tools and equipment.
- e. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. S. No.
1	Universal Testing Machine: Capacity - 100 tonnes. Type: Mechanical type digital, electrically Operated. Accessories: (1) Tensile test attachment for flat and round specimen up to 32 mm. (2) Compression test attachment (3) Shear test attachment with sizes of bushes 5,6,8,10,12,16,20,24 mm, (4) Transverse test attachment with bending Punch, (5) Service tools. (6) Operation and maintenance manuals - 2 nos. (7) Hardness attachment	1 to 8 and 12,13
2	Digital Extensometer: Least count - 0.001 mm. Max. Extension = 5 mm. Single dial gauge for 30,40 mm. 60 mm, 80 mm, 100 mm, 125 mm gauge length.	1 to 2
3	Impact Testing Machine: CHARPY Test Apparatus: Pendulum drop angle 140°; Pendulum effective Wt 20-25 kg; Striking velocity of pendulum 5.6 m/sec; Pendulum impact energy 300 J; Min scale graduation 2 mm distance from axis of pendulum rotation	9, 10



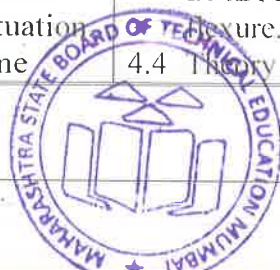
S. No.	Equipment Name with Broad Specifications	PrO. S. No.
	from center of specimen to specimen hit by pendulum 815 mm. IZOD Impact Test Apparatus: Pendulum drop angle: 90°-120; Pendulum effective Wt: 20-25 kg; Striking velocity of pendulum: 3-4 m/sec; Pendulum impact energy: 168 j; Min scale graduation: 2 J; Distance of axis of pendulum rotation from center of specimen to specimen hit by pendulum : 815 mm	
4	Torsion Testing Machine: Fixed with auto torque selector to regulate torque ranges Contains geared motor to apply torque to specimen through gearbox Attached with autographic recorder for relation between torque and angle of twist Accuracy + 1 % of the true torque Suitable For: Torsion and Twist test on diverse metal rods and flats Torque Measurement by pendulum dynamometer system	14, 15
7	Compression Testing Machine: Digital display manual control compression testing; machine; Max. Capacity (KN): 2000 ; Measuring range: 4%-100% of FS; Relative error of reading: $\leq \pm 1\%$; Max. distance between two platen (mm): 330; Compression platen size (mm): 220×220; Max. piston stroke (mm): 0-20; Max. piston speed (mm/min): Approx. 30; Column clearance (mm): 300×200; Oil pump motor power (KW): 1.5; Whole dimensions (mm): 855*380*1435	12, 13
8	Strain Gages set: CEA-13-125UR-350 Strain Gages; CEA-00-125UR-350 Strain Gages; CEA-00-125UT-350 Strain Gages. With strain gauge data logger and connecting cables.	16
9	Freeware/open source software for drawing SF and BM diagrams.	11

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit –I Moment of Inertia	1a. Calculate MI of the given standard shape. 1b. Calculate MI of the given simple composite shape. 1c. Explain with sketches effect of change in MI in case of the given beam and column. 1d. Calculate Polar MI and radius of gyration for the given body.	1.1 Concept of Moment of Inertia (MI), Effect of MI in case of beam and column. 1.2 MI about axes passing through centroid, Parallel and Perpendicular axes theorem, Polar MI, radius of gyration. 1.3 MI of standard basic shapes. 1.4 MI of Composite plane figures.
Unit– II Simple Stress and Strains	2a. Calculate axial deformation and axial stress for the given stress condition. 2b. Use Hooke's law for the	2.1 Equilibrium, Rigid body, Deformable body. 2.2 Axial Stress- meaning, Resistance, Types of stresses; Axial (linear) Strain – concept.

	<p>given stress condition.</p> <p>2c. Calculate Modulus of Elasticity and Rigidity for the given situation.</p> <p>2d. Determine nature and magnitude of thermal stress in the given situation.</p> <p>2e. Draw stress-strain curve of the given ductile and brittle material(s) in tension.</p> <p>2f. Calculate shear stresses for the given single/double shear condition.</p>	<p>types.</p> <p>2.3 Hooke's Law, Young's Modulus, Axial deformation in a body and bodies in series.</p> <p>2.4 Behavior of ductile and brittle materials subjected to axial tension, stress-strain or Load-deformation curve, Limit of proportionality, yielding, permanent set, yield stress, ultimate stress.</p> <p>2.5 Shear stress and shear strain, Modulus of rigidity, punching shear, shear connectors, single and double shear.</p> <p>2.6 Temperature stress and strain in case of bodies having uniform cross-section, deformation fully prevented, field examples.</p>
<p>Unit – III Mechanics I Properties and Elastic Constants of Metals</p>	<p>3a. Identify type of deformation for the given type of load with justification.</p> <p>3b. Evaluate different mechanical properties of the given material.</p> <p>3c. Identify types of load acting in the given situation with justification.</p> <p>3d. Identify type of material from the given data with justification.</p> <p>3e. Calculate strain and axial deformation in each direction under the given bi- and tri-axial stresses.</p> <p>3f. Estimate Resilience, Modulus of resilience, Proof Resilience for the given case.</p>	<p>3.1 Types of loads (actions) and related deformations. Flexure, torsion, shear.</p> <p>3.2 Mechanical properties: Elasticity, Plasticity, Ductility, Brittleness, Malleability. Fatigue, Creep, Toughness, Hardness.</p> <p>3.3 Strength, Factor of Safety, Stiffness and flexibility.</p> <p>3.4 Linear and lateral strain, Poisson's ratio, changes in lateral dimension.</p> <p>3.5 Uni- Bi –Tri-axial stress systems, strain in each direction, Bulk modulus, volumetric strain.</p> <p>3.6 Relation between three moduli.</p> <p>3.7 Stress due to Gradual, Sudden and Impact load, corresponding deformation. Strain Energy, Resilience, Proof Resilience and Modulus of resilience.</p>
<p>Unit-IV Shear Force - Bending Moment and Shear Stresses- Bending Stresses</p>	<p>4a. Calculate SF and BM for the given load and beam.</p> <p>4b. Draw SFD and BMD for the given loaded beam.</p> <p>4c. Locate point of maximum BM and point of contra-flexure in the given case.</p> <p>4d. Draw deflected shape of beam from the given BMD.</p> <p>4e. Use flexural formula for the given bending situation.</p> <p>4f. Draw NA and extreme</p>	<p>4.1 Types of Beams (Simply supported with or without overhang, Cantilever) , Types of loads (Point load, Uniformly Distributed load), Bending of beam, deflected shape.</p> <p>4.2 Meaning of SF and BM, Relation between them, Sign convention.</p> <p>4.3 SFD and BMD. Location of point of maximum BM. Deflected shape from BMD. Location of Point of Contra-flexure.</p> <p>4.4 Theory of simple bending. Assumptions in</p>



	<p>fibers in bending for the given beam.</p> <p>4g. Determine Section modulus and Moment of resistance for the given beam.</p> <p>4h. Determine bending stress and shear stress for the given load and beam.</p> <p>4i. Draw bending stress and shear stress variation diagram for the given beam.</p>	<p>theory of bending. Flexural formula, Neutral axis.</p> <p>4.5 Moment of resistance, Section modulus.</p> <p>4.6 Bending stress variation diagram across depth for cantilever and simply supported beam for symmetrical and unsymmetrical sections.</p> <p>4.7 Transverse shear stress, average and maximum shear stress, Shear stress variation diagram.</p>
Unit-V Torsion	<p>5a. Use torsional equation in the given situation</p> <p>5b. Calculate torque and power transmitted by a shaft in the given situation.</p> <p>5c. Determine shear stress and angle of twist in a shaft for the given power to be transmitted/torque.</p> <p>5d. Determine diameter of shaft for the given shear stress/ angle of twist.</p>	<p>5.1 Torsion: Concept, field applications (Shaft, flange couplings, shear bolts), torsional rigidity, torsional equation and assumptions.</p> <p>5.2 Torsional resistance for hollow and solid circular shafts, Power transmitted by shaft, replacement of section.</p>
Unit-VI Direct and Bending Stresses	<p>6a. Identify machine components subjected to eccentricity with justification.</p> <p>6b. Calculate resultant stress and draw resultant stress variation diagram for the given situation.</p> <p>6c. Mark core (kernel) of the given standard section.</p> <p>6d. Determine size of component for the given stress condition.</p>	<p>6.1 Axial and eccentric load, effects of eccentricity, Field cases (Hook, clamp, Bench Vice, Frame etc).</p> <p>6.2 Axial stress and bending stress, resultant stress intensities, resultant stress variation (Eccentricity about one axis only).</p> <p>6.3 Limiting eccentricity, Core of section.</p> <p>6.4 No tension condition.</p>

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'



9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Moment of Inertia	04	02	00	04	06
II	Simple stresses and Strains	08	02	02	06	10
III	Mechanical properties and Elastic Constants	08	02	02	04	08
IV	Shear force- Bending Moment and Shear stresses- Bending stresses	16	02	06	20	28*
V	Torsion	06	00	02	06	08
VI	Direct and Bending stresses	06	02	02	06	10
Total		48	10	14	46	70

Legends: R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)

Note: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.

* These 28 marks should be equally divided between 'Shear force- Bending Moment' and 'Shear stresses- Bending stresses', hence questions of 14 marks should be asked from each of these topics.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related *co-curricular* activities which can be undertaken to accelerate the attainment of the various outcomes in this course. Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews.

- Undertake micro-projects.
- Prepare journals based on practical performed in laboratory.
- Poster presentation on any one topic.
- Market survey specific to properties of various type of materials used in Mechanical Engineering

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

- Massive open online courses (*MOOCs*) may be used to teach various topics/sub topics.
- 'L' in item No. 4 does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
- About **15-20% of the topics/sub-topics** which is relatively simpler or descriptive in nature is to be given to the students for *self-directed learning* and assess the development of the COs through classroom presentations (see implementation guideline for details).
- With respect to item No.10, teachers need to ensure to create opportunities and provisions for *co-curricular activities*.
- Guide student(s) in undertaking micro-projects.
- Demonstrate students thoroughly before they start doing the practice.



- g. Encourage students to refer different websites to have deeper understanding of the subject.
- h. Observe continuously and monitor the performance of students in Lab.
- i. Show video/animation film to demonstrate the testing of different materials.
- j. Arrange a visit to nearby material testing lab.
- k. Use flash/animations to explain the failure of different machine components under various load situations.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be **individually** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should **not exceed three**.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than **16 (sixteen) student engagement hours** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

- a. Collect information and present in tabular form, values of different engineering properties of five standard mechanical engineering materials.
- b. Present a seminar on different testing methods used in industry.
- c. Prepare models of single and double shear conditions.
- d. Prepare a model of a shaft to demonstrate relation between length and angle of twist.
- e. Prepare an excel sheet to calculate SF and BM in a simply supported beam and cantilever beam.
- f. Collect information comprising of different machine components subjected to direct and bending stresses.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Strength of Materials	Punmia B.C.	Laxmi Publications (p) Ltd. New Delhi, 10/e, 2015, ISBN: 9788131809259
2	Strength of Materials	Ramamurtham S.	Dhanpat Rai Publishing . New Delhi; 2014. ISBN: 9789384378264
3	Strength of Materials	Timoshenko Gere	CBS, 2 edition, 2006, New Delhi, ISBN: 9788123908946
4	Strength of Materials	Khurmi R.S.	S. Chand Publishing, New Delhi, 2006 , ISBN: 9788121928229
5	Strength of Materials	Rattan S.S.	McGraw Hill Education; . New Delhi. 2016. ISBN: 9789385965517



14. SUGGESTED SOFTWARE/LEARNING WEBSITES

- a. nptel.iitm.ac.in/courses/.../IIT.../lecture%2023%20and%2024.htm
- b. en.wikipedia.org/wiki/Shear_and_moment_diagram
- c. www.freestudy.co.uk/mech%20prin%20h2/stress.pdf
- d. www.engineerstudent.co.uk/stress_and_strain.html
- e. https://www.iit.edu/arc/workshops/pdfs/Moment_Inertia.pdf

