GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-III

Course Title: Mechanics of Structures
(Course Code: 4330602)

Diploma programme in which this course is offered	Semester in which offered
Civil Engineering, Environment Engineering	Third Semester

1. RATIONALE

After learning Mechanics of rigid bodies in the second semester as a course Engineering Mechanics, Mechanics of Structures mainly deals with analysis of deformable structures. The primary purpose of the study of this course is to understand the behavior of various structural elements like beams, columns and truss members (struts/ties) under direct and transverse loads. Study of slope and deflection of beams will give insight to students about 'Stiffness', a very important property of the structure. This course enables the student to analyse the determinate structure and this will be helpful for safe and economical design of Steel & Concrete Structures used in Civil Engineering construction. Hence, this course is also a prerequisite of design of structure.

2. COMPETENCY

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

- **Use the principle of Mechanics of Structures to solve broad-based engineering related problems.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Analyse structural behaviour of various materials under axial loading.
b) Determine moment of inertia of a symmetrical and asymmetrical section about a given axis.
c) Draw and Interpret shear force and bending moment diagrams and determine the bending and shear stresses in beams for various types and loading conditions.
d) Determine slope and deflection in cantilever and simply supported beams.
e) Determine axial forces in the members of simple truss.
f) Analyse the column for axial load with various end conditions.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	150

(*):Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment 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, **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. *Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'*.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Conduct tension test on a given sample of mild steel and draw stress-strain curve.	I	04*
2	Determine Young's Modulus of wire of given material.	I	02*
3	Find out Compressive Strength of Cast Iron, Mild Steel, Wooden specimen with parallel & perpendicular to grains & Concrete cube.	I	04*
4	Determine Izod impact value and Charpy impact value of given materials.	I	04*
5	Compute Polar Moment of Inertia of Fly Wheel.	II	02*
6	Conduct flexural test on wooden beam and find out ultimate bending stress.	III,IV	02*
7	Conduct shear test (Single and Double shear) on mild steel and cast iron specimen.	III,IV	02*
8	Find out deflection of cantilever beam for end point load and simply supported beam for central point load	V	02*
9	Analyse at least two simple trusses using analytical method (method of joints) and verify with graphical method.	VI	04*
10	Demonstrate End Conditions of Column.	VII	02*
	Total hours		**28 Hrs.**

Note

i. *More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Identify components	10
2	Prepare experimental setup.	20
3	Operate the equipment setup.	20

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
4	Follow safe practices .	10
5	Record observations correctly.	20
6	Interpret the result and conclude.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to usher in uniformity of practicals in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Universal Testing Machine with beam and shear attachment.	1,6 &7
2	Searl's apparatus to find Young's modulus of wire	2
3	Compression Testing Machine.	3
5	Izod & Charpy Impact Test Apparatus	4
4	Fly Wheel for polar moment of inertia	5
7	Deflection of beam apparatus	8
8	Working Model of End conditions of column	10

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above mentioned COs and PrOs. More could be added to fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Direct Stress & Strain	1a. Evaluate Material properties Under Longitudinal and Lateral Loads. 1b. Calculate stress and strain under thermal variation. 1c. Interpret stress strain curve for various material. 1d. Analyse composite & compound section for stress and strain. 1e. Compute Strain Energy under different types of loading on elements.	1.1 Direct stress, Linear strain, Elasticity, Elastic limit, Hook's law, Modulus of Elasticity or Young's modulus, Stress Strain curve for mild steel bar under tension with numerical problems. 1.2 Lateral stress and strain, Poisson's ratio, Volumetric strain, Bulk modulus, relation between three moduli and numericals. 1.3 Basics Concepts of Shear Stress , Shear Strain & Modulus of rigidity. 1.4 Concept of composite and compound section, modular ratio and numericals. 1.5 Concept of Thermal stress and strain, Thermal stresses for non-yielding and yielding condition with numericals. 1.6 Stresses due to gradual, sudden and impact load, corresponding deformation, Strain energy, Resilience, Proof resilience and Modulus of resilience with numericals.
Unit – II Moment of Inertia	2a. Locate the axis of symmetry & Centroidal axis in symmetrical & asymmetrical solid and hollow sections 2b. Apply Parallel axis theorem to determine moment of inertia, for symmetrical & asymmetrical sections about centroidal axis and any other reference axis. 2c. Apply Perpendicular axis theorem to determine Polar Moment of Inertia of a section.	2.1. Importance of Moment of Inertia. 2.2. Axis of symmetry, Centroidal axis and axis of reference. 2.3. Parallel Axis Theorem & Perpendicular Axis Theorem 2.4. Formulas to calculate Moment of Inertia of solid and hollow rectangle, square, circle, triangle shapes (without derivations). 2.5. Moment of Inertia of symmetrical and asymmetrical I-section, Channel section, T-section, Angle section, Hollow sections and Built up sections about Centroidal axis and any other reference axis using Parallel axis theorem. 2.6. Polar Moment of Inertia of solid & hollow circular sections.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– III **S.F. & B. M. in Beam**	3a. Identify statically determinate and statically indeterminate beams. 3b. Analyse statically determinate beam for Bending Moment and Shear Force. 3c. Draw Shear Force and Bending Moment diagram for statically determinate beams. 3d. Interpret Shear Force and Bending Moment diagram of statically determinate beams.	3.1 Statically Determinate and statically indeterminate beam examples. 3.2 Concept of Bending Moment and Shear Force in beam. 3.3 Sagging and Hogging Bending Moment. Positive and Negative Shear Force. 3.4 Calculation of Bending Moment and Shear Force at various sections of beam for cantilever simply supported and overhang beam subjected to point load and/ or u.d.l. 3.5 S.F. & B.M. Diagram for above beams 3.6 Point of Contra-flexure & its importance.
Unit– IV Bending & Shear Stress in Beam	4a. Determine Bending stress at a particular section of beam using the bending equation. 4b. Draw a Bending stress distribution diagram for a particular beam section. 4c. Determine Shear stress at a particular section of beam using the shear equation. 4d. Draw a Shear stress distribution diagram for a particular beam section. 4e. Identify factors affecting Bending and Shear stress.	4.1 Concept and theory of pure bending, assumptions, Bending equation (without derivation), Section Modulus, Bending stresses and their nature, Bending stress distribution diagram. 4.2 Concept of moment of resistance and simple numerical problems using bending equation. 4.3 Shear stress equation (without derivation), relation between maximum and average Shear stress for rectangular and circular section. 4.4 Shear stress distribution for square, rectangular, circle, hollow square, rectangular, circular, angle sections, channel section, I-section, T section. Simple numerical problems based on Shear equation.
Unit– V Slope and Deflection	5a. Differentiate between strength and stiffness of structural member. 5b. Calculate maximum slope and deflection in cantilever and simply supported beams under symmetrical loads. 5c. Identify factors affecting slope and deflection.	5.1 Concept of Slope & Deflection of beams. 5.2 Flexural rigidity and its significance. 5.3 Formulas (without derivation) of maximum slope & deflection for cantilever beams subjected to point load at free end and u.d.l. Over the entire span. 5.4 Formulas (without derivation) of maximum slope & deflection for simply supported beams subjected to point load at center and u.d.l. over the entire span.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– VI Analysis of Truss	6a. Suggest the type of truss for given situation with proper justification. 6b. Differentiate perfect, deficient and redundant truss 6c. Analyse the simple truss using the method of joints. 6d. Analyse the simple truss using a graphical method.	6.1 Type of truss - Simple, fink, compound fink, Howe truss, Pratt truss, North light truss, king post truss, queen post truss, French truss. Compare the simple truss with the beam. 6.2 Perfect, deficient and redundant truss. 6.3 Analysis of different trusses to find out axial forces in members using analytical method (method of joint) and graphical method.
Unit– VII Column & Strut	7a Interpret various column end conditions 7b Analyse column for load carrying capacity with Euler's theory 7c Analyse column for load carrying capcity with Rankine's theory	7.1 Column and Strut, radius of gyration, slenderness ratio, Short Column and Long Column. 7.2 End conditions & effective length of column. Mode of failure in column. 7.3 The limitations of Euler's theory for short column, Euler's formula for crippling load of long columns and numericals. 7.4 Rankin's formula for buckling load of short & long columns and numericals.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Direct Stress & Strain**	**10**	**2**	**4**	**8**	**14**
II	**Moment of Inertia**	**04**	**2**	**2**	**4**	**08**
III	**S.F. & B. M. in Beam**	**08**	**2**	**4**	**8**	**14**
IV	**Bending & Shear Stress in Beam**	**06**	**2**	**2**	**6**	**10**
V	**Slope and Deflection**	**04**	**2**	**2**	**4**	**08**
VI	**Analysis of Truss**	**06**	**2**	**2**	**6**	**10**
VII	**Column & Strut**	**04**	**2**	**2**	**2**	**06**
Total		**42**	**14**	**18**	**38**	**70**

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

Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.*

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:

a) Collect different situations with photographs of a structural members where axial force is predominant.
b) Collect the photographs of steel structural elements made of I-section, angle section, channel section and built-up section.
c) Collect different situations with photographs of a structural members where bending moment and shear force are predominant
d) Collect the photographs of five different types of truss in the field.
e) Collect the information with photographs of structural failure due to excessive axial load.
f) Collect the information with photographs of structural failure due to excessive bending moment
g) Collect the information with photographs of structural members having excessive deflection (beyond permissible limit)
h) Collect the information with photographs of failure of columns due to earthquake.

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:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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 (group of 3 to 5). However, **in the fifth and sixth semesters**, 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 duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Prepare spreadsheet or computer program to calculate the stresses in the composite section.
b) Compare tensile strength and cost of three locally available structural steel bars.
c) Compare modulus of elasticity of wires of three different materials using Searle's apparatus.
d) Prepare spreadsheet or computer program to calculate the support reactions of statically determinate beams.
e) Prepare spreadsheet or computer program to calculate the bending stress and shear stress in a beam having a rectangular or circular section.
f) Analyse statically determinate beam using freeware software.
g) Prepare spreadsheet or computer program to calculate slope and deflection of simply supported beam and cantilever beam for various load cases.
h) Calculate modulus of elasticity of a material by measuring deflection of beam.
i) Using drafting software, analyse the truss graphically.
j) Analyse the truss using freeware software.
k) Prepare spreadsheet or computer program to calculate safe load on column using Euler's and Rankine's formula.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Mechanics of Structures (Vol.-I)	Dr. H.J. Shah & S.B. Junnarkar	Charotar Publication, Anand. (2016) ISBN: 97-893-850-392-70
2	Strength of Materials (Mechanics of Solids)	R.S.Khurmi N. Khurmi	S Chand Publishing, Delhi (2019) ISBN: 97-893-528-339-79
3	Strength of Materials	Dr. R.K.Bansal	Laxmi Publications(P) Ltd. New Delhi(2005) ISBN: 97-881-700-814-70
4	Strength of Materials	S. Ramamrutham & R.Narayanan	Dhanpat Rai Publishing Company (2011) ISBN:97-881-874-335-45
5	Theory of Structures	R.S.Khurmi	S Chand Publishing, Delhi (2000) ISBN: 97-881-219-052-06

14. SOFTWARE/LEARNING WEBSITES

a) https://nptel.ac.in/courses/105104160 (NPTEL Course :- Mechanics of Solids by IIT, Kanpur)

b) https://www.youtube.com/watch?v=GkFgysZC4Vc&list=PL27C4A6AEA552F9E6 (NPTEL Video Lectures by IIT, Kharagpur)

c) www.vlab.co.in (Virtual Lab by Ministry of Education, Government of India)

15. PO-COMPETENCY-CO MAPPING

Semester III	**Mechanics of Structures (Course Code: 4330602)**						
	POs						
Competency & Course Outcomes	**PO 1 Basic & Discipline specific knowledge**	**PO 2 Problem Analysis**	**PO 3 Design/ development of solutions**	**PO 4 Engineering Tools, Experimentation &Testing**	**PO 5 Engineering practices for society, sustainability & environment**	**PO 6 Project Management**	**PO 7 Life-long learning**
Competency	Use the principle of Mechanics of Structures to solve broad-based engineering related problems.						
Course Outcomes COa) Analyse structural behaviour of various materials under axial loading.	2	3	-	3	2	2	2
COb) Determine moment of inertia of a symmetrical and asymmetrical section about a given axis.	2	3	-	2	2	2	2
COc) Draw and Interpret shear force and bending moment diagrams and determine the bending and shear stresses in beams for various types and loading conditions.	2	3	-	-	2	2	2

COd) Determine slope and deflection in cantilever and simply supported beams.	2	3	-	3	2	2	2
COe) Determine axial forces in the members of simple truss.	2	3	-	-	2	2	2
COf) Analyse the column for axial load with various end conditions.	2	3	-	2	2	2	2

*Legend: '**3'** for high, '**2**' for medium, **'1'** for low and **'-'** for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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