ADVANCED FINITE ELEMENT METHODS AND APPLICATIONS

Course Code	**MMMD/MMDE201**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	03:02:00	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 10-12 Lab slots	Total Marks	100
Credits	04	Exam Hours	03

Course objectives:

1. Introduce basic aspects of finite element technology, including domain discretization, polynomial interpolation, application of boundary conditions, assembly of global arrays, and solution of the resulting algebraic systems.
2. Discuss the use of finite element methods in engineering problem-solving drawing from applications in solid mechanics and other engineering Domains.
3. Familiarize students with professional-level finite element software.
4. To define, derive and assemble stiffness matrices for spring element, truss element, beam elements, Plane Stress element.
5. To be familiar with the idea of Isoperimetric formulation for various FE Elements
6. FE Formulation of Axisymmetric and Solid Elements.

MODULE-1 (8 Hours)

Mathematical Preliminaries: Principle of Virtual Work, General steps of the Finite Element Method.

Introduction to the Stiffness (Displacement) Method: Definition of the Stiffness Matrix, Derivation of the Stiffness Matrix for a Spring Element, Example of a Spring Assemblage, Assembling the total Stiffness Matrix by Superposition Method, Boundary Conditions, Potential Energy Approach to Derive Spring Element Equations.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2 (8 Hours)

Development of Truss Equations: Derivation of the Stiffness Matrix for a Bar Element in Local Coordinates, Selecting a Displacement Function, Transformation of vectors in Two Dimensions, Global Stiffness Matrix for Bar Arbitrarily Oriented in the Plane, Computation of Stress for a Bar in the x – y Plane, Solution of a Plane Truss, Transformation Matrix and Stiffness Matrix for a Bar in three-Dimensional space, Inclined Supports, Potential Energy Approach to Derive Bar Element Equations, Galerkin's Residual Method and its Use to Derive the One-Dimensional Bar Element Equations.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3 (8 Hours)

Development of Beam Equations: Beam stiffness, Example of Assemblage of Beam Stiffness Matrices, Examples of Beam analysis Using the Direct stiffness Method, Distributed Loading, Beam Element with Nodal Hinge, Potential Energy Approach to Derive Beam Element Equations, Galerkin's Method for Deriving Beam Element Equations.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4 (8 Hours)

Development of the Plane Stress and Plane Strain Stiffness Equations: Basic Concepts of Plane Stress and Plane Strain, Derivation of the Constant-Strain triangular Element Stiffness Matrix and Equations, Treatment of body and Surface Forces, Explicit Expression for the Constant-Strain Triangle Stiffness Matrix, Finite Element Solution of a Plane Stress Problem, Rectangular Plane Element (bilinear rectangle, Q4).

Development of the Linear Strain Triangle Equations: Derivation of the Linear-Strain Triangular Element Stiffness Matrix and Equations, Example LST Stiffness Determination, Comparison of Elements.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5 (8 Hours)

Isoparametric Formulation: Isoparametric Formulation of the Bar Element Stiffness Matrix, Isoparametric Formulation of the plane Quadrilateral (Q4) Element Stiffness Matrix, Newton-Cotes and Gaussian Quadrature, Evaluation of the Stiffness Matrix and Stress Matrix by Gaussian Quadrature, Higher-Order Shape Functions (including Q6, Q8,Q9, and Q12 Elements without stiffness matrix derivation)

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Sl.NO.	Experiments
1	Solve (with MATLAB), the ODE using the weak formulation (FEM/MATLAB): $a\frac{d^2u}{dx^2} + b\frac{du}{dx} + cu = f(x)$, $0 < x < L$ with Boundary Conditions: $u(0) = 0$ and $u(L) = 0$ take a=1, b=-3, c=2 and f(x)=1. Take domain size as 1 (i.e. L=1) and take Five linear elements of equal size.
2	Solve (with MATLAB), the ODE using the weak formulation (FEM/MATLAB): $a\frac{d^2u}{dx^2} + b\frac{du}{dx} + cu = f(x)$, $0 < x < L$ with Boundary Conditions: $u(0) = 0$ *and* $\frac{du}{dx}(1) = 0$ take a=1,b=-3, c=2 and f(x)=1. Take domain size as 1(i.e. L=1) and take Five linear elements of equal size.
3	Solve using MATLAB, the Laplace equation representing two dimensional steady-state problems using both linear triangle elements with the given boundary conditions: $$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0 \text{ for } 0 < x < 5 \text{ and } 0 < y < 10.$$ The boundary conditions are u(x, 0) =0 for 0<x<5, u(0,y)=0 for 0<y<10, u(x,10)=100sin(ϖx/10) for 0<x<5, and $\frac{\partial u(5,y)}{\partial x}$ =0 for 0<y<10.
4	Solve the problem 3 using the bilinear rectangular elements with other conditions remaining same.
5	Write a MATLAB program to Use Gauss-Legendre quadrature for integration of $f(x,y) = 1 + 4xy - 3x^2y^2 + x^4y^6$ over the domain -1<x<1 and -1<y<1. Use 3-point quadrature rule along the x-axis and 4-point quadrature rule along y-axis.
6	Determine the natural frequency of a free bar (Fixed at one end and free at other) using the finite element method. The bar has Young's Modulus of 200 GPa, Cross-sectional area of 0.001 m^2 , Density of 7860 Kg/m^3 and Length of 4 m.
7	Write a MATLAB program to perform stress analysis of a cantilever beam subjected to end load using two dimensional Isoparametric elements assuming plane stress condition. Model the beam using ten four-node quadrilateral elements.
8	Write a generalised MATLAB Code that can solve any two dimensional truss structure to find member forces.
9	Make a report of available 1D, 2D and 3D Elements in a commercial FE Software.
10	Make a report of the practical aspects to be considered while generating a mesh in commercial software.
Demonstration Experiments	
11	Solve a problem of a Cantilever beam subjected to end point load in a commercial software to find out its displacements and stresses
12	Write a script in commercial software to automate the above problem for various dimensions and material properties.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

CIE for the theory component of IPCC

- Two Tests each of **25 Marks**
- Two assignments each of **25 Marks/One Skill Development Activity of 50 marks**
- Total Marks of two tests and two assignments/one Skill Development Activity added will be CIE for 60 marks, marks scored will be proportionally scaled down to **30 marks**.

CIE for the practical component of IPCC

- On completion of every experiment/program in the laboratory, the students shall be evaluated and marks shall be awarded on the same day. The **15 marks** are for conducting the experiment and preparation of the laboratory record, the other **05 marks shall be for the test** conducted at the end of the semester.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for **10 marks**. Marks of all experiments' write-ups are added and scaled down to **15 marks**.
- The laboratory test at the end /after completion of all the experiments shall be conducted for **50 marks** and scaled down to **05 marks.**

Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **20 marks**.

SEE for IPCC

Theory SEE will be conducted by the University as per the scheduled timetable, with common question papers for the course (duration 03 hours)

- The question paper will be set for 100 marks and marks scored will be scaled down proportionately to 50 marks.
- The question paper will have ten questions. Each question is set for 20 marks.
- There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
- The students have to answer 5 full questions, selecting one full question from each module.

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper shall include questions from the practical component).

- The minimum marks to be secured in CIE to appear for SEE shall be the 15 (50% of maximum marks-30) in the theory component and 10 (50% of maximum marks -20) in the practical component. The laboratory component of the IPCC shall be for CIE only. However, in SEE, the questions from the laboratory component shall be included**.** The maximum of 04/05 questions to be set from the practical component of IPCC, the total marks of all questions should not be more than the 20 marks.

conducted for 100 marks and students shall secure 40% of the maximum marks to qualify in the SEE. Marks secured will
wn to 50. (Student has to secure an aggregate of 50% of maximum marks of the course (CIE+SEE)

Suggested Learning Resources:

Books

1. Daryl L. Logan, "A First Course in the Finite Element Method", 6th Edition, Cengage Learning, 2017.
2. Jacob Fish and Ted Belytschko, "A First Course in Finite Elements", John Wiley & Sons, 2007
3. J. N. Reddy, "An Introduction to the Finite Element Method", 3rd Edition, Mc-Graw Hill, 2006
4. Ferreira, Antonio & Fantuzzi, Nicholas., "MATLAB Codes for Finite Element Analysis: Solids and Structures", Springer, 2009.

Web links and Video Lectures (e-Resources):

1. NOC: Finite Element Method: Variational Methods to Computer Programming, IIT Guwahati (https://nptel.ac.in/courses/112103295)
2. NOC:Basics of Finite Element Analysis - II, IIT Kanpur (https://nptel.ac.in/courses/112104205)
3. Abaqus FEA Tutorial Videos (https://www.youtube.com/user/AbaqusPython)

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

1. Write MATLAB/ SCILAB programs to Analyse the 1D, 2D, and 3D Finite Elements.
2. Practice the Modelling, Meshing, and Analysis of simple structures in commercial software and compare the results with closed form solutions.
3. Take an open source FE Software, Compile, and generate an executable file.
4. Understand and summarise the format of the input ASCII files generated by commercial meshing software for any well know FE Solver.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Understand the Basis of formulation of Finite Element Methods	2
CO2	Formulate the complete FE Formulation for 1D, 2D, and 3D Elements	3
CO3	Evaluate various boundary conditions in the FE Application	5
CO4	Write a small computer program to analyse a simple Truss structure	6

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/ investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	**3**	**1**	**1**	**3**	**3**
CO2	**3**	**2**	**1**	**3**	**3**
CO3	**3**	**3**	**1**	**3**	**2**
CO4	**1**	**3**	**1**	**1**	**1**

Note : High - 1, Medium – 2, and Low – 3

Modern Vibration Theory and Application			
Course Code	**MMMD/MMDE202**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. To study the basic concepts of vibration.
2. To characterize the free and forced vibrations of damped and undamped single degree of freedom systems.
3. To understand the transient vibration response of a single degree of freedom system.
4. To study various vibration measuring instruments.
5. To study and characterize the random vibrations.
6. To characterize the continuous systems.
7. To study the basic principles of maintenance and condition monitoring.

MODULE-1

"Introduction to vibrations, Importance of studying vibrations, Types of vibrations: Free and Forced, Damped and Undamped, Basic concepts: Periodic motion, Harmonic motion, Frequency, Amplitude, Phase, Free vibration of Single Degree of Freedom (SDOF) systems, Damping concepts: Light damping, Critical damping"

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving, Laboratory Demonstrations and Practical Experiments

MODULE-2

"Forced vibrations with harmonic excitation, Resonance concept and simple examples, Quality factor (Q-factor), Bandwidth, Vibration Isolation: Basic principles, Vibration measuring devices: basic operation"

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving, Laboratory Demonstrations and Practical Experiments

MODULE-3

"Introduction to Two Degree of Freedom (2DOF) systems, Coupled oscillations, Natural frequencies and mode shapes (conceptual level), Basic ideas about Multi-Degree of Freedom (MDOF) systems, Simple modal analysis, Importance of modes in practical systems"

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving, Laboratory Demonstrations and Practical Experiments

MODULE-4

Introduction: Transverse Vibration of a String or Equation of Motion, Initial and Boundary Conditions, Free Vibration of a Uniform String, Free Vibration of a String with Both Ends Fixed,Traveling-Wave Solution.

Longitudinal Vibration of a Bar or Rod: Equation of Motion and Solution, Orthogonality of Normal Functions.

Torsional Vibration of a Shaft or Rod, Lateral Vibration of Beams : Equation of Motion, Initial Conditions, Free Vibration, Boundary Conditions.

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving, Laboratory Demonstrations and Practical Experiments

MODULE-5

Introduction, Transducers: Variable Resistance Transducers, Piezoelectric Transducers, Electrodynamics Transducers, Linear Variable Differential Transformer Transducer.

Vibration Pickups: Vibrometer, Accelerometer, Velometer, Phase Distortion.

Frequency Measuring Instruments Vibration Exciters: Mechanical Exciters, Electrodynamic Shaker, Signal Analysis: Spectrum Analyzers, Bandpass Filter, Constant-Percent Bandwidth and ConstantBandwidth Analyzers.

Dynamic Testing of Machines and Structures: Using Operational Deflection-Shape Measurements, Using Modal Testing,

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving, Laboratory Demonstrations and Practical Experiments

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Two Unit Tests each of **25 Marks**
2. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Francis S. Tse, Ivan E. Morse, Rolland T. Hinkle, "Mechanical Vibrations - Theory and Applications", Allyn and Bacon, Inc., 2004, ISBN-10: 8123908466 / ISBN-13: 978-8123908465.
2. S. Graham Kelly, "Mechanical Vibrations – Theory and Applications", Cengage Learning, 2012, ISBN-10: 1-4390-6214-5 / ISBN-13: 978-1-4390-6214-2.
3. Amiya R. Mohanty, "Machinery Condition Monitoring", CRC Press, 2015, ISBN-13: 978-1-4665-9305-3.

Web links and Video Lectures (e-Resources):

1. NOC:Introduction to Mechanical Vibration, IITRoorkee (https://nptel.ac.in/courses/112107212)
2. Mechanical Vibrations, IIT Guwahati (https://nptel.ac.in/courses/112103112)
3. http://va-coep.vlabs.ac.in/List%20of%20experiments.html

Skill Development Activities Suggested

1. Write MATLAB/ SCILAB programs to simulate the response of single degree of freedom systems under free and forced vibrations.
2. To create mathematical models of single degree of freedom systems in MATLAB Simulink / SCILAB.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Understand the basics of vibrations and determine the equations of motion for free & forced vibrations of single degree of freedom systems and to find their solution	3
CO2	Determine the response of a single degree of freedom system subjected to various types of input forces.	4
CO3	Apply fundamentals of vibrations to its measurement and analysis	6
CO4	Determine the equations of motion for continuous system and to find their solutions.	3
CO5	Understand the basic concepts of maintenance and to apply these concepts for condition monitoring of machines	4

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research /investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	1	3	2
CO2	3	3	1	2	1
CO3	3	3	1	3	2
CO4	2	3	1	3	1
CO5	1	3	1	2	2

Note : High - 1, Medium – 2, and Low – 3

ADVANCED MACHINE DESIGN			
Course Code	**MMMD/MMDE203**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	03:00:00	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

The students will be able to:

1. Outline the basic philosophy of machine design
2. Compute the required load under various practical conditions
3. Apply the various static load based theories of failures
4. Apply the various fatigue load based theories of failures

MODULE-1

Introduction to Mechanical Engineering Design: Design and Mechanical Engineering Design, Phases and Interactions of the Design Process, Design Tools and Resources, The Design Engineer's Professional Responsibilities, Standards and Codes, Stress and Strength, Design Factor and Factor of Safety, Reliability, Dimensions and Tolerances, Calculations and Significant Figures.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2

Load Determination: Loading Classes, FBDs, Load Analysis, 2D Static Loading Case Studies, 3D Static Loading Case Studies, Impact Loading, Beam Loading.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3

Stress and Strain: Stress, Strain, Principal Stress, Plane Stress and Plane Strain, Mohr's Circle, Applied Versus Principal Stresses, Axial Tension, Direct Shear Stress, Bearing Stress and Tearout,

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4

Deflection: Beams and Bending Stresses, Deflection in Beams, Torsion, Combined Stresses, Spring Rates, Stress Concentration, Stresses in Cylinders, Case Studies In Static Stress And Deflection Analysis.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5

Static Failure Theories: Failure of Ductile Materials, Failure of Brittle Materials, Case Studies: Bicycle Brake Lever, Crimping Tool, Automobile Scissors- jack, Bicycle Brake Arm.

Teaching-	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Learning Process	

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

3. Two Unit Tests each of **25 Marks**
4. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module
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Suggested Learning Resources:

Books

1. Robert L. Norton, Machine design - An Integrated Approach, 4th Edition, Prentice- Hall, 2011
2. R G Budynas, and J K Nisbett, Shigley's Mechanical Engineering Design, 9th Edition, McGraw Hill,2011

Web links and Video Lectures (e-Resources):

1. https://www.machinedesign.com/
2. https://archive.nptel.ac.in/courses/112/105/112105125/
3. https://archive.nptel.ac.in/courses/112/105/112105124/

Skill Development Activities Suggested

1. Write a small C Program to design a shaft for both static and dynamic loading
2. Compute the fatigue life of simple rod subject to constant amplitude load in a commercial software
3. Learn the usage of MSC Fatigue Module of NASTRAN

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Define basic philosophies used in Machine Design	2
CO2	Design and Analyse any geometrically well-defined component subjected to static loading	1
CO3	Design and Analyse a simple component subjected to fatigue loading	4

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/ investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**3**	**3**	**1**	**1**	**1**
CO2	**3**	**2**	**1**	**3**	**1**
CO3	**3**	**2**	**1**	**2**	**1**

Note : High - 1, Medium – 2, and Low – 3

Computer Simulation of Machines

Course Code	**MMMD/MMDE206**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	03:00:00	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

This course will enable students to

1. Know the concepts used for kinematic analysis of planar and spatial mechanisms.
2. Familiarize with the concepts of synthesis of mechanisms.

MODULE-1(8 Hours)

Introduction: Elements of Mechanisms, degrees of freedom, Kutchback equation and Grublerscriterion -applications of Grublers criterion, transmission angles- extreme values of transmissionangles, toggle positions. Introduction to Vector Loop and Vector Chain Equations. The Planar Vector, Single LoopEquations, Derivatives of Vectors.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2(8 Hours)

Path Curvature Theory: Hartmann construction, Euler Savary Equation, BobilliersConstruction.
Introduction to synthesis (analytical methods): Freudenstein's equation and problems,Block synthesis and problems, Reven's method and its problems.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3(8 Hours)

Kinematic Synthesis: Introduction, type, dimensional and number Synthesis, synthesis for function generation, path and motion generation, Chebyschev Spacing of accuracy points.
Graphical Synthesis Techniques: Motion generation for two prescribed positions and three prescribed positions – path generation for three prescribed positions without and with prescribed timing – function generation for three prescribed positions.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4(8 Hours)

Analytical Synthesis Techniques: Four-bar and slider crank function generator with threeaccuracy points– use of complex numbers and dyads – three prescribed positions for motion,path and function generation using dyad.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5(8 Hours)

Spatial Mechanisms: Introduction, Position analysis problem, Velocity and acceleration analysis, Eulerian angles, D-H transformation matrix; forward kinematic analysis of serial manipulators.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

5. Two Unit Tests each of **25 Marks**
6. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module
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Suggested Learning Resources:

Books

1. Uicker, Pennock and Shigley," Theory of machines and Mechanisms", Oxford University Press, 2010.
2. AmitabhaGhosh and Ashok Kumar Mallik, "Theory of Mechanism and machines", East West Press pvt Ltd, 2nd edition.
3. S.S. Rattan, "Theory of Machines", Tata McGraw Hill, 2011.
4. Arthur G. Erdman, George N. Sandor, "Advanced Mechanism Design: Analysis and Synthesis, Volume 2", Prentice-Hall, 1984 .

Web links and Video Lectures (e-Resources):

1. NOC:Kinematics of Mechanisms and Machines, IITKharagpurhttps://nptel.ac.in/courses/112105268
2. Kinematics Of Machineshttps://www.youtube.com/watch?v=MJeRFzs4oRU&list=RDCMUC640y4UvDAlya_WOj5U4pfA&index=2

Skill Development Activities Suggested

1. Write a MATLAB Program for kinematic analysis of Fourbar mechanism
2. Write a program in MATLAB to simulate the forward kinematics of a 2R Robotic Arm.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Apply path curvature characteristics in analysis of mechanisms.	2
CO2	Apply analytical and synthesis techniques in design of mechanisms.	1
CO3	Apply forward and reverse kinematic analysis techniques in performance evaluation of manipulators	4

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/ investigation and development work to solve practical problems.	1
2	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
3	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
4	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**3**	**-**	**1**	**2**	**1**
CO2	**3**	**-**	**1**	**1**	**2**
CO3	**3**	**-**	**1**	**3**	**2**

Note : High - 1, Medium – 2, and Low – 3

Mechanical Simulation Laboratory			
Course Code	**MMMDL/MMDEL207**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	00:00:03:00	SEE Marks	50
Credits	03	Exam Hours	03

Course objectives:

By the end of this course, students will be able to:
1. Apply Finite Element Analysis (FEA) to solve structural problems and understand stress, strain, and deformation in mechanical components.
2. Analyze multi-body dynamic systems using simulation tools to evaluate kinematics and dynamic behaviours of mechanisms.
3. Implement computational optimization techniques to improve the performance and efficiency of mechanical structures.
4. Model and simulate mechanical systems such as gears, trusses, and linkages using industry-standard software.
5. Utilize machine learning techniques for the classification of material properties based on mechanical characteristics.

**** Software mentioned are representative only, any other equivalent commercial or open source software can be used**

Sl.NO	Experiments
1	**Static Structural Analysis of a Cantilever Beam** • **Objective:** Analyze a **cantilever beam** subjected to a point load. • **Software:** MSC Nastran / MATLAB • **Outcome:** Understanding **stress, displacement, and boundary conditions**.
2	**Modal Analysis of a Plate Structure** • **Objective:** Compute the **natural frequencies and mode shapes** of a rectangular plate. • **Software:** MSC Nastran / Python • **Outcome:** Learning **eigenvalue analysis** for vibration studies.
3	**Multi-Body Dynamic Simulation of a Four-Bar Mechanism** • **Objective:** Simulate a **four-bar linkage** and analyze motion parameters like velocity and acceleration. • **Software:** MSC Adams • **Outcome:** Understanding **kinematic and dynamic behavior of mechanisms**.
4	**Finite Element Analysis of a 2D Truss Structure** • **Objective:** Solve a **2D truss problem** using the **stiffness matrix method**. • **Software:** MATLAB / MSC Nastran • **Outcome:** Understanding **axial forces, stress distribution, and deformations**.
5	**Optimization of Structural Components using Quadratic Programming** • **Objective:** Optimize a mechanical component **subjected to constraints using quadratic programming**. • **Software:** Python (cvxopt) • **Outcome:** Exposure to **optimization techniques in mechanical design**.
6	**Multi-Body Dynamic Analysis of a Suspension System** • **Objective:** Simulate and analyze a **vehicle suspension system** under a road profile. • **Software:** MSC Adams • **Outcome:** Understanding **shock absorption, damping, and ride comfort**.
7	**Computational Analysis of a Simple Gear Train** • **Objective:** Model and simulate a **gear train** to evaluate torque transmission and speed ratios. • **Software:** MSC Adams • **Outcome:** Understanding **gear motion, forces, and efficiency**.
8	**Machine Learning-Based Classification of Material Properties** • **Objective:** Apply **K-Means and Fuzzy C-Means clustering** to classify materials based on mechanical properties. • **Software:** Python (scikit-learn, NumPy) • **Outcome:** Understanding **unsupervised learning applications in material classification**.
	Demonstration Experiments (For CIE) if any
9	**Buckling Analysis of a Slender Column** • **Objective:** Simulate buckling behavior of a **column under axial compression**. • **Software:** MSC Nastran

	• **Outcome:** Understanding **critical load determination and stability analysis**.
10	**Impact Analysis of a Drop Test on a Mechanical Component** • **Objective:** Simulate an impact test for a **falling object striking a rigid surface**. • **Software:** MSC Nastran / MATLAB • **Outcome:** Understanding **stress wave propagation and impact forces**.
11	**Fatigue Analysis of a Rotating Shaft** • **Objective:** Perform a **fatigue life prediction** for a rotating shaft under cyclic loading. • **Software:** MSC Nastran • **Outcome:** Understanding **failure prediction and fatigue cycles**.
12	**Topology Optimization of a Mechanical Bracket** • **Objective:** Optimize the **shape and material distribution** of a mechanical bracket to minimize weight while maintaining strength. • **Software:** MSC Nastran / MATLAB • **Outcome:** Understanding **design optimization and lightweight structures**.

Course outcomes (Course Skill Set):

At the end of the course the student will be able to:

- **Perform static and dynamic analysis** of mechanical components using FEA-based software like MSC Nastran and MATLAB.
- **Simulate and evaluate motion characteristics** of multi-body systems such as linkages, suspensions, and gear trains using MSC Adams.
- **Solve optimization problems** in mechanical engineering using Python-based quadratic programming techniques.
- **Analyze real-world mechanical problems** and validate results through computational simulations.
- **Apply AI-based clustering techniques** to classify materials based on their mechanical properties using Python.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each course. The student has to secure not less than 40% of maximum marks in the semester-end examination(SEE). In total of CIE and SEE student has to secure 50% maximum marks of the course.

Continuous Internal Evaluation (CIE):

CIE marks for the practical course is **50 Marks**.

The split-up of CIE marks for record/ journal and test are in the ratio **60:40**.

- Each experiment to be evaluated for conduction with an observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments designed by the faculty who is handling the laboratory session and is made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- **Total marks scored by the students are scaled down to 30 marks** (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct 01 tests for 100 marks, test shall be conducted after the 14th week of the semester.
- In test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.
- The suitable rubrics can be designed to evaluate each student's performance and learning

Semester End Evaluation (SEE):

SEE marks for the practical course is 50 Marks.

SEE shall be conducted jointly by the two examiners of the same institute, examiners are appointed by the University.

All laboratory experiments are to be included for practical examination.

(Rubrics) Breakup of marks and the instructions printed on the cover page of the answer script to be strictly adhered to by the examiners. **OR** based on the course requirement evaluation rubrics shall be decided jointly by examiners.

Students can pick one question (experiment) from the questions lot prepared by the internal /external examiners jointly.

Evaluation of test write-up/ conduction procedure and result/viva will be conducted jointly by examiners.

General rubrics suggested for SEE are mentioned here, writeup-20%, Conduction procedure and result in -60%, Viva-voce 20% of maximum marks. SEE for practical shall be evaluated for 100 marks and scored marks shall be scaled down to 50 marks (however, based on course type, rubrics shall be decided by the examiners)

Change of experiment is allowed only once and 10% Marks allotted to the procedure part to be made zero.

The duration of SEE is 03 hours

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each course. The student has to secure not less than 40% of maximum marks in the semester-end examination(SEE). In total of CIE and SEE student has to secure 50% maximum marks of the course.

Continuous Internal Evaluation (CIE):

CIE marks for the practical course is **50 Marks**.

The split-up of CIE marks for record/ journal and test are in the ratio **60:40**.

- Each experiment to be evaluated for conduction with an observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments designed by the faculty who is handling the laboratory session and is made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- **Total marks scored by the students are scaled down to 30 marks** (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct 01 tests for 100 marks, test shall be conducted after the 14th week of the semester.
- In test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.

Semester End Evaluation (SEE):

SEE marks for the practical course is 50 Marks.

SEE shall be conducted jointly by the two examiners of the same institute, examiners are appointed by the University.

All laboratory experiments are to be included for practical examination.

(Rubrics) Breakup of marks and the instructions printed on the cover page of the answer script to be strictly adhered to by the examiners. **OR** based on the course requirement evaluation rubrics shall be decided jointly by examiners.

Students can pick one question (experiment) from the questions lot prepared by the internal /external examiners jointly.

Evaluation of test write-up/ conduction procedure and result/viva will be conducted jointly by examiners.

General rubrics suggested for SEE are mentioned here, writeup-20%, Conduction procedure and result in -60%, Viva-voce 20% of maximum marks. SEE for practical shall be evaluated for 100 marks and scored marks shall be scaled down to 50 marks (however, based on course type, rubrics shall be decided by the examiners)

Change of experiment is allowed only once and 10% Marks allotted to the procedure part to be made zero.

The duration of SEE is 03 hours

Suggested Learning Resources:

Books and Reference Materials

1. **Zienkiewicz, O.C., & Taylor, R.L.** (2013). *The Finite Element Method: Its Basis and Fundamentals* (7th ed.). Elsevier.
2. **Chandrupatla, T.R., & Belegundu, A.D.** (2011). *Introduction to Finite Elements in Engineering* (4th ed.). Pearson.
3. **Madier, D.** (2018). *Practical Finite Element Analysis* (1st ed.). Independently Published.
4. **Nakasone, Y., Yoshimoto, S., & Stolarski, T.** (2017). *Engineering Analysis with ANSYS Software* (2nd ed.). Butterworth-Heinemann.
5. **Gattringer, H., & Gerstmayr, J.** (2013). *Multibody System Dynamics, Robotics and Control* (1st ed.). Springer.
6. **Shabana, A.A.** (2013). *Dynamics of Multibody Systems* (4th ed.). Cambridge University Press.
7. **Flores, P., & Lankarani, H.M.** (2015). *Introduction to Multibody Dynamics: Solutions and Practical Applications* (1st ed.). Springer.
8. **Boyd, S., & Vandenberghe, L.** (2004). *Convex Optimization* (1st ed.). Cambridge University Press.
9. **Bishop, C.M.** (2006). *Pattern Recognition and Machine Learning* (1st ed.). Springer.
10. **Nagarajan, R.** (2021). *Data Science for Engineers* (1st ed.). Cambridge University Press.
11. **Meriam, J.L., & Kraige, L.G.** (2016). *Engineering Mechanics: Dynamics* (8th ed.). Wiley.
12. **Hibbeler, R.C.** (2021). *Mechanics of Materials* (10th ed.). Pearson.

Online Resources and Websites

1. **MSC Software Learning Hub** – https://www.mscsoftware.com/
2. **Finite Element Analysis Blog** – https://www.simscale.com/blog/
3. **Introduction to FEA** (MIT OpenCourseWare) – https://ocw.mit.edu/courses/mechanical-engineering/
4. **MSC Adams Tutorials** – https://www.mscsoftware.com/products/adams
5. **Multibody Dynamics Simulations** – https://www.comsol.com/multibody-dynamics-module
6. **Python Quadratic Programming (cvxopt)** – https://cvxopt.org/
7. **SciPy for Structural Analysis** – https://scipy.org/
8. **Machine Learning Crash Course by Google** – https://developers.google.com/machine-learning/crash-course
9. **Scikit-learn Documentation (K-Means & Fuzzy C-Means)** – https://scikit-learn.org/

Ability /Skill Enhancement Courses

Numerical Programming for Mechanical Engineers (Using MATLAB/NumPy)		Semester	02
Course Code	**MMMD/MMDE258A**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	0:0:0:2	SEE Marks	50
Total Hours of Pedagogy	15	Total Marks	100
Credits	01	Exam Hours	1 Hour
Examination type (SEE)	**MCQ**		

Note: Instead of MATLAB any equivalent open source and commercial software can be used

Course objectives:

By the end of this course, students will be able to:

1. Gain knowledge of basic numerical methods and algorithms used in mechanical engineering.
2. Understand the mathematical foundations and applications of numerical techniques.
3. Learn to use MATLAB and NumPy for numerical problem-solving in mechanical engineering contexts.
4. Familiarize with key concepts in solving linear and nonlinear equations, interpolation, and numerical differentiation.
5. Learn to apply numerical methods for mechanical engineering simulations and error analysis.

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teachers can use to accelerate the attainment of the various course outcomes.

1. Hands-On Coding Assignments
2. Lab Sessions
3. Project-Based Learning
4. Interactive Demonstrations
5. Comparative Analysis
6. Visualizations
7. Regular Quizzes and Tests
8. Continuous Feedback and Assessment

Module-1

Introduction to Numerical Programming

Overview of Numerical Methods: Basic definitions and examples of numerical methods, Significance of numerical programming in engineering. **Introduction to MATLAB and NumPy:** Syntax, commands, and basic operations, Understanding variables, matrices, and vectors. **Basic Programming Constructs:** Loops, conditional statements, and functions, Debugging techniques in MATLAB/NumPy

Module-2

Solving Linear and Nonlinear Equations:

Linear Systems of Equations: Gaussian elimination, LU decomposition. **Iterative methods:** Jacobi and Gauss-Seidel. **Nonlinear Equations:** Bisection method, Newton-Raphson method, Fixed-point iteration

Module-3

Numerical Differentiation and Integration:

Numerical Differentiation: Forward and backward difference methods, Central difference approximation. **Numerical Integration:** Trapezoidal rule, Simpson's rule

Module-4

Interpolation and Curve Fitting:

Polynomial Interpolation: Lagrange and Newton interpolation methods,Application to curve fitting.Least Squares Method: Fitting a linear model to data points

Module-5

Numerical Solutions of Ordinary Differential Equations (ODEs)
Introduction to ODEs: Types of ordinary differential equations in mechanical engineering, Initial value and boundary value problems.
Numerical Methods for ODEs: **Euler's method, Runge-Kutta methods (4th order)**

Course outcome (Course Skill Set)

At the end of the course the student will be able to::

1. Identify the appropriate numerical method for a given engineering problem.
2. Understand and recognize various methods for solving equations, integration, and interpolation.
3. Select suitable algorithms for solving ODEs in mechanical engineering.
4. Evaluate the accuracy of numerical methods and identify common sources of error.
5. Apply numerical methods to basic mechanical engineering problems using MATLAB/NumPy.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks (25 marks out of 50) and for the SEE minimum passing mark is 40% of the maximum marks (20 out of 50 marks). The student is declared as a pass in the course if he/she secures a minimum of 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous internal Examination (CIE)

- For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assignment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Internal Assessment Test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examinations (SEE)

SEE paper shall be set for 50 questions, each of the 01 marks. The pattern of the question paper is MCQ (multiple choice questions). The time allotted for SEE is **01 hour.** The student has to secure a minimum of 40% of the maximum marks meant for SEE.

Suggested Learning Resources:

Books

1. **"Numerical Methods for Engineers"** by Steven C. Chapra and Raymond P. Canale
2. **"Applied Numerical Methods with MATLAB for Engineers and Scientists"** by Steven C. Chapra
3. **"Numerical Methods in Engineering with Python 3"** by Jaan Kiusalaas
4. **"MATLAB for Engineers"** by Holly Moore
5. **"Python for Engineers and Scientists"** by E.M. Kranakis

Web links and Video Lectures (e-Resources):

1. **MATLAB Documentation:** https://www.mathworks.com/help/matlab/
2. **NumPy Documentation:** https://numpy.org/doc/stable/
3. **MIT OpenCourseWare - Numerical Methods:** https://ocw.mit.edu/courses/mechanical-engineering/
4. **Coursera - Numerical Methods for Engineers:**https://www.coursera.org/learn/numerical-methods-engineering
5. **SciPy Documentation (for advanced numerical computing):** https://docs.scipy.org/doc/scipy/

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Collaborative Learning
- Gamification of Learning
- Online Code Repositories

Python Programming for Beginners		Semester	02
Course Code	MMMD/MMDE258B	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	0:0:0:2	SEE Marks	50
Total Hours of Pedagogy	15	Total Marks	100
Credits	01	Exam Hours	1 Hour
Examination type (SEE)	**MCQ**		

By the end of this course, students will be able to:

1. Understand the fundamentals of Python programming, including variables, control structures, and data types.
2. Develop basic Python scripts to solve computational problems.
3. Understand and use functions, libraries, and modules to enhance programming capabilities.
4. Learn to work with files and handle exceptions in Python.
5. Apply Python programming skills to solve practical, real-world problems in mechanical engineering and other domains.

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teachers can use to accelerate the attainment of the various course outcomes.

1. Hands-On Coding Assignments
2. Lab Sessions
3. Project-Based Learning
4. Interactive Demonstrations
5. Comparative Analysis
6. Visualizations
7. Regular Quizzes and Tests
8. Continuous Feedback and Assessment

Module-1

Introduction to Python Programming

- **Python Basics:** Variables, data types, and basic operators.
- **Control Structures:** If-else conditions, loops (for, while).
- **Basic Input/Output:** Reading from and writing to the console.

Module-2

Data Structures and Collections

- **Lists and Tuples:** Creating and manipulating lists and tuples.
- **Dictionaries and Sets:** Using dictionaries for key-value pairs, and sets for unique elements.
- **List Comprehensions:** Efficiently creating and modifying lists.

Module-3

Functions and Modular Programming

- **Functions:** Defining and calling functions, parameters, and return values.
- **Lambda Functions:** Anonymous functions for compact code.
- **Modules:** Importing and using Python standard libraries.

Module-4

File Handling and Exception Handling

- **Reading and Writing Files:** Handling text and binary files.
- **Exception Handling:** Try-except blocks to manage errors gracefully.
- **Context Managers:** Using with statements for file management.

Module-5

Introduction to Libraries for Engineering Applications

- **NumPy:** Arrays, mathematical operations, and linear algebra.
- **Matplotlib:** Basic plotting and visualization for engineering data.
- **Integration with Mechanical Systems:** Simple Python applications to solve engineering problems.

Course outcome (Course Skill Set)

At the end of the course the student will be able to::

1. Write and execute simple Python programs.
2. Implement control structures (e.g., loops, conditionals) and data structures (e.g., lists, dictionaries).
3. Create and call functions to modularize and reuse code.
4. Handle errors and exceptions to ensure program stability.
5. Use libraries such as NumPy and Matplotlib for basic engineering calculations and data visualization.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks (25 marks out of 50) and for the SEE minimum passing mark is 40% of the maximum marks (20 out of 50 marks). The student is declared as a pass in the course if he/she secures a minimum of 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous internal Examination (CIE)

- For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assignment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Internal Assessment Test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examinations (SEE)

SEE paper shall be set for 50 questions, each of the 01 marks. The pattern of the question paper is MCQ (multiple choice questions). The time allotted for SEE is **01 hour.** The student has to secure a minimum of 40% of the maximum marks meant for SEE.

Suggested Learning Resources:

Books

1. **"Automate the Boring Stuff with Python"** by Al Sweigart
2. **"Python Crash Course"** by Eric Matthes
3. **"Learning Python"** by Mark Lutz
4. **"Python for Data Analysis"** by Wes McKinney
5. **"Python Programming: An Introduction to Computer Science"** by John Zelle

Web links and Video Lectures (e-Resources):

1. **Python Official Documentation:**https://docs.python.org/3/
2. **W3Schools Python Tutorial:** https://www.w3schools.com/python/
3. **Python for Everybody (Coursera):**https://www.coursera.org/specializations/python
4. **NumPy Documentation:** https://numpy.org/doc/stable/
5. **Matplotlib Documentation:** https://matplotlib.org/stable/contents.html

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

1. **Interactive Online Coding Platforms:**
   Encourage students to practice coding through interactive platforms like **Replit**, **Jupyter Notebooks**, or **Google Colab** where they can run Python code directly in their browsers.
2. **Project-Based Learning:**
   Assign small projects where students can apply the concepts learned in the modules. Example projects could include writing a Python script to calculate the area of mechanical components, plotting data from experiments, or solving simple mathematical problems related to mechanical engineering.
3. **Online Tutorials and Video Resources:**
   Provide links to YouTube channels or online courses that explain the course concepts in depth, such as **Corey Schafer's Python tutorials** or the **Python for Everybody** Coursera series.

Multi-Body Simulation using VTU's CoE Software		Semester	02
Course Code	MMMD/MMDE258C	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	0:0:0:2	SEE Marks	50
Total Hours of Pedagogy		Total Marks	100
Credits	01	Exam Hours	1 Hour
Examination type (SEE)	**MCQ**		

Course objectives:

1. Introduce fundamental multi-body dynamics concepts.
2. Teach students kinematic and dynamic analysis of mechanisms.
3. Familiarize students with contact forces and flexible bodies in simulations.
4. Develop skills in pre-processing, simulation, and result interpretation.
5. Apply basic design and optimization techniques in simulations.

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teachers can use to accelerate the attainment of the various course outcomes.

1. Hands-On Coding Assignments
2. Lab Sessions
3. Project-Based Learning
4. Interactive Demonstrations
5. Comparative Analysis
6. Visualizations
7. Regular Quizzes and Tests
8. Continuous Feedback and Assessment

Module-1

Introduction to Multi-Body Simulation: Concepts Covered: Degrees of Freedom (DOF), joints, constraints, motion simulation. **Software Used:** MSC Adams

Experiments:

1. **Kinematic Analysis of a Four-Bar Mechanism** – Simulate motion and measure angular velocity.
2. **Dynamic Simulation of a Slider-Crank Mechanism** – Analyze displacement and acceleration.

Module-2

Basic Structural Integration in MBD:Concepts Covered: Rigid vs. flexible bodies, introduction to modal analysis. **Software Used:** MSC Adams, MSC Nastran

Experiments:

3. **Rigid Body vs. Flexible Body Simulation of a Beam –** Convert a beam from rigid to flexible and observe the difference.
4. **Basic Modal Analysis of a Simple Structure –** Perform a modal analysis and integrate it in MSC Adams.

Module-3

Contact Forces and Friction in Mechanisms: Concepts Covered: Contact modeling, friction, force analysis. Software Used: MSC Adams

Experiments:

5. **Simulation of a Simple Gear Pair** – Model gear contact forces in MSC Adams.
6. **Effect of Friction on a Sliding Block** – Analyze a block sliding on an inclined plane with different friction coefficients.

Module-4

Vehicle and Suspension System Basics: Concepts Covered: Suspension dynamics, vehicle stability. Software Used: MSC Adams

Experiments:

7. **Simulation of a Basic Suspension System** – Study the displacement and forces in a simplified double-wishbone suspension.
8. **Steering System Kinematics** – Model a rack-and-pinion mechanism and analyze wheel movement.

Module-5

Design Optimization and Basic System Analysis: Concepts Covered: Parameter optimization, system improvement. Software Used: MSC Adams

Experiments:

9. **Optimization of a Simple Linkage Mechanism** – Adjust link lengths to improve efficiency.
10. **Analysis of a Bouncing Ball with Damping** – Model motion with varying damping coefficients.

Course outcome (Course Skill Set)

At the end of the course the student will be able to::

1. Simulate basic multi-body mechanisms using MSC Adams.
2. Perform kinematic and dynamic analysis of simple mechanical systems.
3. Understand contact forces and frictional effects in moving systems.
4. Integrate basic flexible body behavior into multibody simulations.
5. Apply optimization techniques for system improvement.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks (25 marks out of 50) and for the SEE minimum passing mark is 40% of the maximum marks (20 out of 50 marks). The student is declared as a pass in the course if he/she secures a minimum of 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous internal Examination (CIE)

- For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assignment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Internal Assessment Test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examinations (SEE)

SEE paper shall be set for 50 questions, each of the 01 marks. The pattern of the question paper is MCQ (multiple choice questions). The time allotted for SEE is **01 hour.** The student has to secure a minimum of 40% of the maximum marks meant for SEE.

Suggested Learning Resources:

Books

1. Shabana, A. A. (2020). Dynamics of Multibody Systems (4th ed.). Cambridge University Press.

2. Nikravesh, P. E. (2007). Computer-Aided Analysis of Mechanical Systems (2nd ed.). Prentice Hall.
3. Schielen, R. M. (2014). Multibody Dynamics for Engineers (1st ed.). Cambridge University Press.
4. Haug, E. J. (1989). Computer-Aided Kinematics and Dynamics of Mechanical Systems (1st ed.). Allyn & Bacon.
5. Zienkiewicz, O. C., Taylor, R. L., & Zhu, J. Z. (2013). The Finite Element Method: Its Basis and Fundamentals (7th ed.). Elsevier.

Web links and Video Lectures (e-Resources):

1. Adams Beginner Tutorial: Simple Four-Bar Mechanism – https://www.youtube.com/watch?v=YsoON-YVvmU
2. MSC ADAMS Tutorial: Slider Crank Mechanism – https://www.youtube.com/watch?v=hYoZ6b3aafQ
3. A Brief Introduction to MSC.ADAMS™ (PDF) – https://mecheng.iisc.ac.in/~asitava/NPTEL/adams-tutorial.pdf
4. Adams Tutorial Kit for Mechanical Engineering Courses – https://hexagon.com/resources/resource-library/adams-tutorial-kit-mechanical-engineering-courses
5. Adams 2021.1: Getting Started Using Adams Machinery (PDF) – https://help-be.hexagonmi.com/bundle/Adams_2021.1_Getting_Started_Using_Adams_Machinery/raw/resource/enus/Adams_2021.1_Getting_Started_Using_Adams_Machinery.pdf
6. MSC ADAMS Tutorials (YouTube Playlist) – https://www.youtube.com/playlist?list=PL2St_Lvz3c0OVuIhCWAXxfSzSZA4qcLfe
7. Four Bar Mechanism Crank Length Optimization via MSC Adams – https://www.youtube.com/watch?v=F3CG-GA9Rh0

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Collaborative Learning
- Gamification of Learning
- Online Code Repositories

3D Printing and Robotic Simulation Programming		Semester	02
Course Code	MMMD/MMDE258D	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	0:0:0:2	SEE Marks	50
Total Hours of Pedagogy	15	Total Marks	100
Credits	01	Exam Hours	1 Hour
Examination type (SEE)	MCQ		

Course objectives:

1. To introduce the core concepts of additive manufacturing and robotic simulation programming.
2. To understand the processes, materials, and applications of 3D printing.
3. To explore the fundamentals of robotic simulation for virtual task planning.
4. To analyze the integration of additive manufacturing and robotics for advanced applications.

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teachers can use to accelerate the attainment of the various course outcomes.

1. Hands-On Coding Assignments
2. Lab Sessions
3. Project-Based Learning
4. Interactive Demonstrations
5. Comparative Analysis
6. Visualizations
7. Regular Quizzes and Tests
8. Continuous Feedback and Assessment

Module-1

Introduction to Additive Manufacturing : Historical Development and Classification of Additive Manufacturing Processes, Process Chain: CAD Model, Slicing, Printing, and Post-Processing, Overview of 3D Printing Technologies: FDM, SLA, SLS, DMLS, Materials for Additive Manufacturing: Polymers, Metals, Ceramics, and Composites, Applications in Aerospace, Healthcare, and Automotive Industries

Module-2

Advanced Additive Manufacturing Processes: Multi-Material and Hybrid Printing Techniques, Lattice Structures and Topology Optimization, Surface Quality, Accuracy, and Post-Processing Methods, Economic and Environmental Considerations, Case Studies of Additive Manufacturing Applications.

Module-3

Fundamentals of Robotic Simulation: Introduction to Industrial Robotics: Kinematics and Dynamics, Basics of Robot Programming and Task Planning, Simulation Platforms: RoboDK, MSC Adams, MATLAB Simulink, Virtual Model Creation and Path Planning, Simulation of Robotic Operations: Assembly, Welding, and Inspection.

Module-4

Multi-Body Simulation and System Analysis : Kinematic and Dynamic Simulation of Multi-Body Systems, Path Optimization and Collision Detection, Virtual Prototyping for Manufacturing and Automation, Failure Prediction through Simulation Analysis, Practical Examples using RoboDK and MSC Adams.

Module-5

Integration and Future Trends: Integration of 3D Printing and Robotic Automation, Digital Twins and Industry 4.0 Applications, Challenges in Process Control and Workflow Synchronization, Emerging Trends: AI in Additive Manufacturing and Robotics, Case Studies and Real-World Implementations.

Course outcome (Course Skill Set)

At the end of the course the student will be able to::

1. Describe the principles, technologies, and workflows of additive manufacturing.
2. Identify appropriate materials and processes for specific 3D printing applications.
3. Simulate robotic operations using virtual programming platforms.
4. Analyze multi-body systems for manufacturing and automation tasks.
5. Evaluate real-world applications of integrated 3D printing and robotics.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks (25 marks out of 50) and for the SEE minimum passing mark is 40% of the maximum marks (20 out of 50 marks). The student is declared as a pass in the course if he/she secures a minimum of 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous internal Examination (CIE)

- For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assignment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Internal Assessment Test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examinations (SEE)

SEE paper shall be set for 50 questions, each of the 01 marks. The pattern of the question paper is MCQ (multiple choice questions). The time allotted for SEE is **01 hour.** The student has to secure a minimum of 40% of the maximum marks meant for SEE.

Suggested Learning Resources:

Books

1. Gibson, I., Rosen, D. W., & Stucker, B. *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing*. Springer, 2015.
2. Siciliano, B., & Khatib, O. *Springer Handbook of Robotics*. Springer, 2016.
3. Chua, C. K., & Leong, K. F. *3D Printing and Additive Manufacturing: Principles and Applications*. World Scientific, 2017.
4. Groover, M. P. *Industrial Robotics: Technology, Programming, and Applications*. McGraw Hill, 2012.

Web links and Video Lectures (e-Resources):

1. NPTEL Course on Additive Manufacturing: https://nptel.ac.in/courses/112/107/112107221/
2. RoboDK Simulation Tutorials: https://robodk.com/doc/en/Getting-Started.html
3. MIT OpenCourseWare: Additive Manufacturing https://ocw.mit.edu/courses/mechanical-engineering/
4. Autodesk Fusion 360 Resources: https://www.autodesk.com/products/fusion-360/overview
5. MSC Adams Learning Hub: https://www.mscsoftware.com/msc-adams

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Collaborative Learning
- Gamification of Learning
- Online Code Repositories

Professional Electives

OPTIMIZATION TECHNIQUES

Course Code	**MMMD/MMDE214A**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. Enumerate the fundamental knowledge of Linear Programming and Dynamic Programming problems.
2. Learn classical optimization techniques and numerical methods of optimization.
3. Know the basics of different evolutionary algorithms.
4. Explain Integer programming techniques and apply different optimization techniques to solve various models arising from engineering areas

MODULE-1

Liner Programming (LP): Revised Simplex Method, Duel simplex Method, Sensitivity Analysis

Dynamic Programming (DP): Multistage decision processes. Concepts of sub optimization, Recursive Relation-calculus method, tabular method, LP as a case of D.P

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2

Classical Optimization Techniques: Single variable optimization without constraints, Multi variable optimization without constraints, multivariable optimization with constraints method of Lagrange multipliers, Kuhn-Tucker conditions.

Numerical Methods For Optimization: Nelder Mead's Simplex search method, Gradient of a function, Steepest descent method, Newton's method

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3

Modern methods of optimization:

Genetic Algorithm (GA): Differences and similarities between conventional and evolutionary algorithms, working principle, Genetic Operators- reproduction, crossover, mutation.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4

Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, Random population generation.

Fuzzy Systems: Fuzzy set Theory, Optimization of Fuzzy systems

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5

Integer Programming: Graphical Representation, Gomory's Cutting Plane Method, Balas' Algorithm for Zero–One Programming, Branch-and-Bound Method.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

7. Two Unit Tests each of **25 Marks**
8. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Singiresu S. Rao," Engineering Optimization Theory and Practice", 4th Edition, John Wiley, 2009
2. Kalyanmoy Deb,Optimization forEngineering Design Algorithms and Examples,2nd Edition, PHI Learning Private Limited, New Delhi, 2012
3. David E. Goldberg,"Genetic Algorithms in Search, Optimization and Machine Learning", Addison-Wesley Longman Publishing Co., Inc, 1989
4. Frederick Hillier and Gerald Lieberman, "Introduction to Operations Research", 11th Edition, Tata Mc Graw Hill, 2021,
5. Jasbir S. Arora, "Introduction to Optimum Design", McGraw - Hill College, 1988

Web links and Video Lectures (e-Resources):

- Optimization Toolbox (https://in.mathworks.com/products/optimization.html)
- S.N. Sivanandam, S.N. Deepa , Principles of Soft Computing, 2nd Edition ,2011
- Principle of Soft computing (https://archive.nptel.ac.in/courses/106/105/106105173/)

Skill Development Activities Suggested

1. One or two exercises of Optimization using MATLAB/Python.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Apply the fundamental knowledge of Linear Programming and Dynamic Programming problems.	3
CO2	Use classical optimization techniques and numerical methods of optimization.	2
CO3	Enumerate fundamentals of Integer programming technique and apply different techniques to solve various optimization problems arising from engineering areas.	2

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**3**	**-**	**1**	**1**	**1**
CO2	**3**	**-**	**1**	**3**	**1**
CO3	**3**	**-**	**1**	**3**	**2**

Note : High - 1, Medium – 2, and Low – 3

FATIGUE AND FRACTURE MECHANICS			
Course Code	**22MDE244**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	30	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. Introduce basic aspects of Fatigue and Failure.
2. Discuss the availability of various fatigue analysis methods that are used by professional.
3. Know the modifications required in case of mean stress and notches
4. To understand various cycle counting methods used in industries and in commercial software.
5. To understand the basic Fracture Mechanics

MODULE-1

Fatigue Damage Theories: Fatigue damage mechanism, Cumulative damage models,Linear damage models,Double linear damage rule by Manson and Halford.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2

Stress-Based Fatigue Analysis and Design: Introduction,The stress-life (S-N) and fatigue limit testing, Estimated SN curve of a component based on ultimate tensile strength, Notch effect, Mean stress effect,Combined proportional loads.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3

Strain-Based Fatigue Analysis and Design: Introduction, Experimental test program, Analysis of monotonic and cyclic stress–strain behaviour of materials,Mean stress correction methods,Estimation of cyclic and fatigue properties,Notch analysis.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4

Cycle Counting Techniques: One-parameter cycle counting methods,Two-parameter cycle counting methods,Four-Point Cycle Counting Method,Reconstruction of a load-time history.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5

Introduction to Fracture Mechanics: assumptions of LEFM, brittle vs. ductile fracture, stress intensity factor (SIF) for Mode I, Mode II, and Mode III, crack tip stress fields, Griffith's energy criterion, Irwin's modification for plastic zone, fracture toughness (K_{IC}) and its measurement, crack tip plasticity models (Irwin and Dugdale), R-curve and stable crack growth, failure prediction, applications in aerospace, automotive, and structural components.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

9. Two Unit Tests each of **25 Marks**
10. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Yung-Li Lee, Jwo Pan, Richard Hathaway, Mark Barkey." Fatigue Testing and Analysis : Theory and Practice", Elsevier, 2005.
2. Julie A. Bannantine, Jess J. Comer, James L. Handrock,"Fundamentals of Metal Fatigue Analysis", Prentice Hall, 1990.
3. Ralph I. Stephens, Ali Fatemi, Robert R. Stephens, Henry O. Fuchs,"Metal Fatigue in Engineering", John Wiley & Sons, 2000.
4. Anderson T L, "Fracture Mechanics: Fundamentals and Applications", 4th Edition, CRC Press, 2017.
5. ASTM Standard E399, "Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness KIc of Metallic Materials," ASTM International.
6. MSC Fatigue 2021.4 (Theory Guide): (https://www.mscsoftware.com)
7. Broek, D. Elementary Engineering Fracture Mechanics, Springer, 1982.

Web links and Video Lectures (e-Resources):

1. Practical Fatigue Theory (Online) (https://www.ncode.com/services/training-courses/practical-fatigue-theory-ncode-training-online)
2. Constant Amplitude Stress-Life Analysis ,(https://www.efatigue.com/constantamplitude/stresslife/#a)
3. Fatigue & Fracture Mechanics in FEA (https://www.nafems.org/training/e-learning/fatigue-fracture-fea/)
4. What is Fatigue Analysis? | MSC Nastran (https://simulatemore.mscsoftware.com/what-is-fatigue-analysis-msc-nastran/)
5. NPTEL Fracture Mechanics Course: https://nptel.ac.in/courses/105/106/105106052/
6. MIT OpenCourseWare - Fracture Mechanics: https://ocw.mit.edu/courses/mechanical-engineering/

Skill Development Activities Suggested

1. Write MATLAB/ SCILAB programs to implement the rain flow counting
2. Run a MSC NASTRAN Fatigue Analysis
3. Try A sample Problem of Spot Welding in MSC Fatigue
4. Explore various Fatigue and Fracture software such as NASGRO, FRANC3D, NISA Endure etc.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Correctly predict Fatigue life of metal components using Stress and Strain life Methods.	3
CO2	Analyse the situation to apply appropriate fatigue failure method	3
CO3	Identify and describe the basic fatigue mechanisms.	2
CO4	Use appropriate Rain counting Method for variable amplitude loading	3

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Program Outcome of this course

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	1	3	1	3	1
CO2	3		1	3	1
CO3	3		1	2	1
CO4	3	3	1	3	3

Note : High - 1, Medium – 2, and Low – 3

SUSTAINABILITY ENGINEERING			
Course Code	**MMMD/MMDE214C**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. To have an increased awareness among students on issues in areas of sustainability
2. To understand the role of engineering and technology with sustainable development.
3. To know the methods, tools and incentives for sustainable products service system development
4. To establish clear understanding of the role and impact t of various aspects of engineering decisions on environmental, societal and economic problems

MODULE-1

Sustainability: Introduction, concept, evolution of the concept; Social, environmental and economic sustainability concepts; Sustainable development, Nexus between Technology and Sustainable development.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2

Environmental Pollution: Air Pollution and its effects, Water pollution and its sources, Zero waste concept and 3 R concepts in solid waste management; Greenhouse effect, Global warming, Climate change, Ozone layer depletion, legal provisions for environmental protection.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3

Environmental Management Standards: ISO 14001:2015 frame work and benefits, Scope and goal of Life Cycle Analysis (LCA),

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4

Resources and its Utilisation: Basic concepts of Conventional and non-conventional energy, General idea about solar energy, Fuel cells, Wind energy, Small hydro plants, bio-fuels,

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5

Sustainability Practices: Basic concept of sustainable habitat, Methods for increasing energy efficiency in buildings, Green Engineering, Sustainable Urbanization, Sustainable cities, Sustainable transport

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

11. Two Unit Tests each of **25 Marks**
12. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Allen, D .T. and Shonnard, D .R., Sustainability Engineering: Concepts, Design and case studies, Prentice Hall
2. Bradley, A.S; Adebayo, A.O; Maria, P, Engineering applications in sustainable design and development, Cengage learning.
3. Environmental Impact assessment guidelines, Notification of Govt of India, 2006.
4. Mackenthun, K M; Basic concepts in Environmental management, Lewis publication, London 1998
5. Ni bin Chang, Systems analysis for sustainable engg Theory and applications, Mcgraw Hill professional.

Web links and Video Lectures (e-Resources):

- VTU e-Shikshana Program
- VTU EDUSAT Program

Skill Development Activities Suggested

- Case study
- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Understand the relevance and the concept of sustainability and the global initiatives in this direction	
CO2	Explain the different types of environmental pollution problems and their	
CO3	Discuss the environmental regulations and standards	
CO4	Outline the concepts related to conventional and non-conventional energy	
CO5	Demonstrate the broad perspective of sustainable practices by utilizing engineering knowledge and principles	

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	**1**	**2**	**3**	**3**	**2**
CO2	**3**	**3**	**1**	**3**	**1**
CO3	**1**	**2**	**1**	**3**	**2**
CO4	**3**	**3**	**1**	**3**	**1**
CO5	**1**	**3**	**1**	**2**	**1**

Note : High - 1, Medium – 2, and Low – 3

Signal Analysis And Condition Monitoring			
Course Code	**MMMD/MMDE214C**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. To study and understand signal and its types
2. To understand the techniques involved in signal conditioning
3. To know the different used in structural health monitoring

MODULE-1

Introduction: Basic concepts. Fourier analysis. Bandwidth. Signal types. Convolution.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2

Signal analysis: Filter response time. Detectors. Recorders. Analoganalyzer types.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3

Practical analysis of stationary signals: Stepped filter analysis. Swept filter analysis. High speed analysis. Real-time analysis.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4

Practical analysis of continuous non-stationary signals: Choice of window type. Choice of window length. Choice of incremental step. Practical details. Scaling of the results.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5

Condition monitoring techniques: Visual monitoring, Thermography, Vibration monitoring, Shock pulse monitoring, Wear debris monitoring, Motor current and signature analysis, Acoustic emission, Ultrasound monitoring, ISO standards, Fault detection sensors, Structural Health M0nitoring (SHM), integrated Vehicle Health Monitoring (IVHM).

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

13. Two Unit Tests each of **25 Marks**
14. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. R. B. Randall, "Frequency Analysis", Brüel&Kjaer, 1987.
2. V. Ramamurti , Mechanical Vibration Practice with Basic Theory, Narosa Publishing House, 2000
3. A.R. Mohanty, Machinery Condition Monitoring: Principles and Practices (ISBN: 9781466593046) CRC Press, 2014
4. Richard G. Lyons, "Understanding digital signal processing", Pearson; third edition (1 November 2010).
5. Alan V.Oppenheim , Alan S.Willsky, S.HamidNawab, "Signal and System",2 nd Edition, Pearson

Web links and Video Lectures (e-Resources):

NPTEL Video Lectures: Machinery Condition Monitoring and Signal Processing by A R MOHANTY

Skill Development Activities Suggested

Industrial visit / internship to gain hands-on experience on various Condition Monitoring methods.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Discuss different types of signals generated	2
CO2	Apply the various techniques for signal conditioning	3
CO3	Apply various condition monitoring techniques	3

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**2**		**1**	**2**	**2**
CO2	**2**		**1**	**3**	**3**
CO3	**2**		**1**	**2**	**2**

Note : High - 1, Medium – 2, and Low – 3

DIGITAL MANUFACTURING			
Course Code	**MMMD/MMDE214E**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	

Course Learning objectives:

1. Understand the Evolution of Industrial Production:
2. Comprehend Digital Manufacturing Systems:
3. Develop Proficiency in CAD and CAM Tools:
4. Explore Additive Manufacturing Technologies:
5. Apply Software and Standards for 3D Printing:

Module-1

Introduction to Digital Manufacturing: Definition of digital manufacturing, Historical perspective on industrial production and outlook, Industrial Revolutions, Industry 4.0, Cyber-physicalsystem,Factoryofthefuture,OperationModeandArchitectureofDigitalManufacturing System.

Module-2

CadModeling:DesignprocessandroleofCAD,Typesandapplicationsofdesignmodels,Three dimensional modelling schemes, Wire frames and surface representation schemes, Solid modelling - Parametric modelling, Assembly modelling.

Module-3

Reverse Engineering: Need, Reverse engineering process, Reverse engineering hardware and software, Geometric model development.

ComputerAidedManufacturing: Componentmodelling,Machineandtoolselection,Defining process and parameters, Tool path generation, Simulation, Post processing.

Module-4

Additive Manufacturing for Digital Transformation: Introduction to additive manufacturing, Additive manufacturing process chain, Material selection, Manufacturing, Post processing, Additive manufacturing technologies and processes, Vat photo polymerization, Material extrusion, Material jetting, Sheet lamination, Powder bed fusion, Binder jetting, Planning and slicing additive manufacturing software.

Module-5

Concept Modelers, Translators and 3D Printing Software: Introduction, Principle, Thermo jet printer, Sander's model market, 3- D printer, Genisys Xs printer, JP system 5, object quadra System-Rapid proto typing. Standard interface to convey geometric description from CAD package to Rapid prototyping system, Stereo Lithography (STL)file, Initial Graphics Exchange Specification(IGES)file, Hewlett-Packard Graphics Language(HP/GL) file.

Additivemanufacturingsoftwareforeditingfeaturesandtoexportfilestoprinters:Ansys, Autodesk Netfabb, 3dSystems, Materialise Magics, Solid Edge, Amphyon.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

15. Two Unit Tests each of **25 Marks**
16. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Zude ZhouShane (Shengquan) Xie Dejun Chen,"Fundamentals of DigitalManufacturingScience''Springer Series in Advanced Manufacturing,2012 (Unit-I)
2. Ibrahim Zeid and Sivasubramanian R, "CAD/CAM - Theory and Practice", Tata McGraw Hill Education, 2011. (Unit-II)
3. VineshRajaandKiranJFernandes,"ReverseEngineering-AnIndustrialPerspective", Springer-Verlag, 2008(Unit-III)
4. Chua C.K., Leong K.F. and Lim C.S., Rapid Prototyping: Principles and Applications, 3rd Edition, World scientific publications, 2014.(Unit-IV&V)
5. Pham D T and Dimov S, "Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping", Springer-Verlag, 2001.
6. GerardJounghyunKim,"DesigningVirtualSystems:TheStructuredApproach", Springer, 2005.
7. AnttiSaaksvuoriandAnselmiImmonen,"ProductLifecycleManagement",Springer, 2004.

Web links and Video Lectures (e-Resources):

1. NPTEL. (2022). *Digital Manufacturing and Industry 4.0.* National Programme on Technology Enhanced Learning (NPTEL), IIT Madras. https://nptel.ac.in/courses/106/106/106106216/
2. Autodesk. (2024). *Autodesk Learning Hub – Fusion 360 & AutoCAD.* https://www.autodesk.com/learning
3. MIT OpenCourseWare. (2019). *Additive Manufacturing – Design and Manufacturing II.* Massachusetts Institute of Technology. https://ocw.mit.edu/courses/mechanical-engineering/2-008-design-and-manufacturing-ii-spring-2019/
4. 3D Systems. (2024). *Learning Center for 3D Printing and Rapid Prototyping.* https://www.3dsystems.com/learning-center

Skill Development Activities Suggested

1. Explore virtual simulations of Industry 4.0 environments.
2. Design 3D CAD models using SolidWorks, AutoCAD, or Fusion 360 or any equivalent software
3. Perform parametric and assembly modeling of components.
4. Practice 3D scanning and geometric reconstruction.
5. Develop CAD models from scanned point cloud data.
6. Generate CNC tool paths using CAM software.
7. Simulate machining and perform post-processing.
8. Design and slice 3D models for printing.
9. Execute 3D printing projects with different materials.
10. Work with STL, IGES, and HP/GL file formats.
11. Edit and optimize 3D models using Netfabb or Magics.
12. Develop a mini-project integrating CAD, CAM, and 3D printing.
13. Conduct case studies on smart factories.
14. Complete online courses on Industry 4.0 or Additive Manufacturing.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	ExplainArchitectureof DigitalManufacturingSystem	2
CO2	Discuss ontheroleof CADand designprocess indigital manufacturing	2
CO3	Explain the application of reverse engineering / discuss on techniques for processing ofCAD models for digital manufacturing	2
Co4	Explaintheprincipalandprocessinvolvedindevelopmentofpartsbyadditive manufacturing	2
CO5	Discussontheuseofdigitalmanufacturingequipment/explaintheroleofsoftwar ein digital manufacturing	2

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5
CO1	3	-	3	1	1
CO2	3	-	3	1	1
CO3	3	-	3	1	1
CO4	1	-	2	1	1
CO5	1	-	2	1	1

MECHANICAL BEHAVIOUR OF MATERIALS			
Course Code	**MMMD/MMDE215A**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. To familiarize the concept of deformation mechanisms in single crystal and polycrystalline materials.
2. To study strengthening mechanisms and mechanics of fracture in ductile and brittle materials
3. To study the fatigue and creep properties of materials under various conditions
4. To familiarize the various characterization techniques used to probe mechanical properties.

MODULE-1(5 Hours)

Plastic Deformation: Concepts of crystals, Plastic deformation by slip and twinning, Slip systems in FCC, BCC and HCP lattices, Critical resolved shear stress for slip, Theoretical shear strength of solids, Stacking faults and deformation bands.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2(5 Hours)

Dislocation Theory : Observation of dislocations, Climb and cross slip, Dislocations in FCC and HCP lattice, Partial dislocations, Stress fields and energies of dislocations, Forces between dislocations, Interaction of dislocations, Dislocation sources and their multiplications.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3(6 Hours)

Strengthening Mechanisms: Strengthening from grain boundaries, Grain size measurements, Yield point phenomenon, Strain aging, Solid solution strengthening, Strengthening from fine particles, Fiber strengthening, Cold working and strainhardening, Annealing of cold worked metal.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4(5 Hours)

Creep and Stress Rupture: Creep curve, Stress rupture test, Mechanism of creep deformation, Activation energy for steady state creep, Superplasticity, Fracture at elevated temperature, Creep resistant alloys, Creep under combined stresses.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5(4 Hours)

The Tension Test: Stress-strain curves, Instability in tension, Ductility measurement, Effect of strain rate, temperature and testing machine on flow properties, Stress relaxation testing, Notch tensile test, Anisotropy of tensile properties.

The Hardness Test: Brinnel, Rockwell and Vickers hardness, flow of metal under the indenter, relationship between hardness and flow curve, micro hardness testing, Hardness at elevated temperatures.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

17. Two Unit Tests each of **25 Marks**
18. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Dieter M. George, Mechanical Metallurgy, McGraw- Hill Inc., 2001.
2. Richard W Hertzberg Deformation and fracture mechanics, John Wiley & Sons
3. Reed Hill and Robert E, Physical Metallurgy Principles, East West Press
4. Hyden W. M. Structure and properties of Materials, Vol. 3, McGraw Hill

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Web links and Video Lectures (e-Resources):

1. Mechanical Behavior of Materials https://onlinecourses.nptel.ac.in/noc21_mm27/preview
2. Mechanical Behaviour of Materials https://onlinecourses.nptel.ac.in/noc22_mm04/preview

Skill Development Activities Suggested

1. Use a strain gage setup to estimate the strains at a surface point of a plate subjected to tensile loading
2. Identify and list the values of SN curves for various alloys of Steel and Aluminium

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Explain the effect of dislocations and their interaction on the material strength	2
CO2	Apply the concept of fracture toughness to material failure	2
CO3	Carry out the Tensile test for a steel specimen	3

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	An ability to write and present a substantial technical report/document.	2
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.	3
4	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
5	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**3**		**1**	**3**	**1**
CO2	**3**		**1**	**2**	
CO3	**1**		**1**	**3**	**1**

Note : High - 1, Medium – 2, and Low – 3

BASICS OF MACHINE LEARNING			
Course Code	MMMD215B	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. To understand the basic theory underlying machine learning.
2. To be able to formulate machine learning problems corresponding to different applications.
3. To understand a range of machine learning algorithms along with their strengths and weaknesses.
4. To be able to apply machine learning algorithms to solve problems of moderate complexity.
5. To apply the algorithms to a real-world problem, optimize the models learned and report on the expected accuracy that can be achieved by applying the models.

MODULE-1(5 Hours)

Introduction to Machine Learning

Introduction, Components of Learning, Learning Models, Geometric Models, Probabilistic Models, Logic Models, Grouping and Grading, Designing a Learning System, Types of Learning, Supervised, Unsupervised, Reinforcement, Perspectives and Issues, Version Spaces, PAC Learning, VC Dimension.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2(5 Hours)

Supervised and Unsupervised Learning

Decision Trees: ID3, Classification and Regression Trees, Regression: Linear Regression, Multiple Linear Regression, Logistic Regression, Neural Networks: Introduction, Perception, Multilayer Perception, Support Vector Machines: Linear and Non-Linear, Kernel Functions, K Nearest Neighbors. Introduction to clustering, K-means clustering, K-Mode Clustering.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3(5 Hours)

Ensemble and Probabilistic Learning

Model Combination Schemes, Voting, Error-Correcting Output Codes, Bagging: Random Forest Trees,
Boosting: Adaboost, Stacking.
Gaussian mixture models - The Expectation-Maximization (EM) Algorithm, Information Criteria,
Nearestneighbour methods - Nearest Neighbour Smoothing, Efficient Distance Computations: the KD-Tree, Distance Measures.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4(5 Hours)

Reinforcement Learning and Evaluating Hypotheses

Introduction, Learning Task, Q Learning, Non deterministic Rewards and actions, temporal-difference learning, Relationship to Dynamic Programming, Active reinforcement learning, Generalization in reinforcement learning. Motivation, Basics of Sampling Theory: Error Estimation and Estimating Binomial Proportions, The

Binomial Distribution, Estimators, Bias, and Variance

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5(5 Hours)

Genetic Algorithms: Motivation, Genetic Algorithms: Representing Hypotheses, Genetic Operator, Fitness Function and Selection, An Illustrative Example, Hypothesis Space Search, Genetic Programming, Models of Evolution and Learning: Lamarkian Evolution, Baldwin Effect, Parallelizing Genetic Algorithms.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

19. Two Unit Tests each of **25 Marks**
20. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module
-

Suggested Learning Resources:

Books

1. Tom M. Mitchell , "Machine learning", McGraw Hill 1997
2. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.
3. RajjanShinghal, "Pattern Recognition", Oxford Press, 2006.
4. EthemAlpaydin, "Introduction to machine learning", PHI learning, 2008.
5. Hastie, Tibshirani, Friedman, "The Elements of Statistical Learning", Springer 2001.
6. R.O. Duda, P.E. Hart and D.G. Stork, Pattern Classification, Wiley-Interscience, 2nd Edition, 2000.
7. T. Hastie, R. Tibshirani and J. Friedman, The Elements of Statistical Learning: Data Mining, Inference and Prediction, Springer, 2nd Edition, 2009

Web links and Video Lectures (e-Resources):

- VTU e-Shikshana Program
- VTU EDUSAT Program

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Activities

- Mini project on live working model/ Problems.
- Seminar
- Assignment

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Choose the learning techniques with this basic knowledge	2
CO2	Apply effectively genetic algorithms for appropriate applications	3
CO3	Apply Bayesian techniques and derive effectively learning rules.	3
CO4	Choose and differentiate Clustering & Unsupervised Learning and Language Learning	2

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program.	3
3	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
4	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5
5		

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1			**1**	**3**	**1**
CO2	**3**		**1**	**2**	**1**
CO3	**3**		**1**	**2**	**1**
CO4	**2**		**1**	**3**	**1**

Note : High - 1, Medium – 2, and Low – 3

DESIGN FOR MANUFACTURING AND ASSEMBLY			
Course Code	**MMMD/MMDE215C**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	25 hours + 10-12 activities	Total Marks	100
Credits	03	Exam Hours	03

Course objectives:

1. Understanding the basic rules for design for manufacturing and material selection.
2. Applying the guidelines for ease of design, manufacturing and assembly.
3. Analyze factors for selection of material and process, relationship to manufacturing processes
4. Apply the concepts of design for manufacturing and assembly for product manufacturing.
5. Compare various manufacturing processes and assembly techniques required for product development to optimise the process.

MODULE-1(5 Hours)

Material and process selection – Introduction, Advantages of applying DFMA, General requirements of early materials and process selection, Selection of Manufacturing processes, Selection of materials. Engineering Design features. – Dimensioning, Tolerances, General Tolerance, Geometric Tolerances,

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2(5 Hours)

Assembly limits, Datum features.
Component design – Machining Considerations – Drills, Milling cutters, Drilling, Keyways, Dowels, Screws, Reduction in machining areas, Simplification by separation and amalgamation, work piece holding, surface grinding, Examples.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3 (5 Hours)

Component design – Casting Considerations – Pattern, Mould, parting line, cast holes, machined holes, identifying parting line, special sand cores, designing to obviate sand cores. Examples

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4(5 Hours)

Design for Injectionmolding and Sheet metal working – Injection molding materials, Molding cycle, Systems, molds, machine size, cycle time, Cost estimation, Insert molding, Design guidelines, Introduction to sheet metalworking.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE 5(5 Hours)

Selective Assembly: Interchangeable part manufacture and selective assembly, deciding the number of groups Group tolerance of Mating parts equal, Model total and group tolerances of shaft equal. Control of axial play- Introducing secondary machining operations, laminated shims, examples.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

21. Two Unit Tests each of **25 Marks**
22. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

- Product Design for Manufacture and Assembly – Geoffrey Boothroyd - Peter Dewhurst - Winston Knight
- Designing for Manufacturing – Harry Peck - Pitman Publications – 1983
- Dimensioning and Tolerancing for Quantity Production – Merhyle F Spotts –Inc. Englewood Cliffs - New Jersey - Prentice Hall, 5thedition.

Web links and Video Lectures (e-Resources):

- VTU e-Shikshana Program
- VTU EDUSAT Program

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Understand the principles of manufacturability and design for manufacture	2
CO2	Design casting for economic production.	4
CO3	Understand the concept of easy assembly, based on rules of DFMA to reduce the time of assembly.	2
CO4	Redesign the parts for easy manufacturing based on rules of DFMA to reduce the time of manufacturing and enhance cost effectiveness.	4
CO5	Design guidelines and background for powder metallurgy parts and reviewing of formed parts.	5

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program.	2
3	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**3**	**2**			**1**
CO2	**1**	**2**			**1**
CO3	**3**	**2**			**1**
CO4	**3**	**2**			**1**
CO5	**3**	**2**			**1**

Note : High - 1, Medium – 2, and Low – 3

DESIGN OF AEROSPACE STRUCTURES			
Course Code	**MMMD/MMDE215D**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. To study basic concepts of aircraft structures & materials, and various types of loads acting on an aircraft.
2. To understand concepts of open and closed thin walled beams.
3. To acquire the knowledge of buckling of plates, joints and fittings.
4. Comprehend the stress analysis on wings and fuselage.

MODULE-1(8 Hours)

Loads on Aircraft and Aircraft Materials:

Loads on Aircraft and Aircraft Materials Loads on Aircraft: Structural nomenclature, Types of loads, load factor, Aerodynamics loads, Symmetric manoeuvre loads, Velocity diagram, Function of structural components.

Aircraft Materials: Metallic and non-metallic materials, Use of Aluminum alloy, titanium, stainless steel and composite materials. Desirable properties for aircraft application.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2(8 Hours)

Bending of Open and Closed Thin Walled Beams:

Symmetrical bending, unsymmetrical bending, direct stress distribution due to bending, position of the neutral axis, load intensity, shear force, and bending moment relationships, deflection due to bending, calculation of section properties, approximation for thin-walled sections.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3(8 Hours)

Shear and Torsion of Open and Closed Thin Walled Beams:

General stress, strain, and displacement relationship for open and single-cell closed section thin-walled beams, shear of open section beams, shear centre, shear of closed section beams. Torsion of close section beam, and displacement associated with the Bredt-Batho shear flow. Torsion of open section beam. Combined bending, shear, torsion.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4(8 Hours)

Buckling of Plates, Joints and Fittings:

Buckling of Isotropic flat plates in compression, ultimate compressive strength of Isotropic flat sheet, plastic buckling of flat sheet, columns subjected to local crippling failure, Needham & Gerard method for determining crippling stress, curved sheets in compression, elastic buckling of curved rectangular plates. Pure tension field beams, angle of diagonal tension in web. Joints and Fittings- bolted or riveted joints, accuracy of fitting analysis, eccentrically loaded connections, welded joints, and concept of effective width.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5(8 Hours)

Stress Analysis in Wing Spars and Box beams: Tapered wing spar, open and closed section beams, beams having variable stringer areas, three- boom shell, torsion and shear, tapered wings, cut-outs in wings.

Stress Analysis in Fuselage Frames: Bending, shear, torsion, cut-outs in fuselages, principles of stiffeners construction, fuselage frames, shear flow distribution.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

23. Two Unit Tests each of **25 Marks**
24. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks**
    to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Megson, T. H. G., "Aircraft Structures for Engineering Students", Edward Arnold, 1995, ISBN-10:
2. Peery D J & Azar J J, "Aircraft Structures", McGraw Hill N.Y, 2^{nd} edition,1993,

3. Bruhn E. F, “Analysis & Design of Flight Vehicles Structures”, Tri-State offset Co, USA, 1985, ISBN-10:

Web links and Video Lectures (e-Resources):

1. Aircraft Structures - I, IIT Kharagpur (https://archive.nptel.ac.in/courses/101/105/101105084/)

Skill Development Activities Suggested

1. Industrial visit at any aerospace organization.

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Understand the various loads acting on aircraft.	2
CO2	Understand various types of materials used in aircraft configuration.	2
CO3	Apply the concept of thin walled beams.	3
CO4	Calculate the buckling of plates.	3
CO5	Analyze the stresses in wings and fuselage structures / frames.	4

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	Students should be able to design, synthesize and analyse a physical engineering systems using modern tools and techniques.	4
3	Students should be able to conduct analytical and experimental investigations on Industrial and societal problems to provide sustainable solutions.	5

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**3**			**2**	**1**
CO2	**3**			**2**	**1**
CO3	**2**			**2**	**1**
CO4	**2**			**2**	**1**
CO5	**1**			**3**	**3**

Note : High - 1, Medium – 2, and Low – 3

INTRODUCTION TO HYBRID AND ELECTRIC VEHICLES			
Course Code	**MMMD/MMDE215E**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

1. Explain the basics of electric and hybrid electric vehicles, their architecture, technologies and fundamentals.
2. Analyze various electric drives suitable for hybrid electric vehicles.
3. Discuss different energy storage technologies used for hybrid electric vehicles and their control.
4. Demonstrate different configurations of electric vehicles and its components, hybrid vehicle configuration by different techniques, sizing of components and design optimization and energy management.

MODULE-1(8 Hours)

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies.

Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-2(8 Hours)

Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-3(8 Hours)

Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-4(8 Hours)

Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems

Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies.

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

MODULE-5(8 Hours)

Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV).

Teaching-Learning Process	Power-point Presentation, Chalk and Talk are used for Problem Solving,

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

25. Two Unit Tests each of **25 Marks**
26. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

- The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
- Each full question will have a sub-question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module
-

Suggested Learning Resources:

Books

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
2. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

3. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

Web links and Video Lectures (e-Resources):

1. Introduction to Hybrid and Electric Vehicles - Web course https://archive.nptel.ac.in/courses/108/103/108103009/
2. Introduction to Hybrid Electric Vehicle Systems PD291809 (https://www.sae.org/learn/content/pd291809/)
3. Electric Vehicle Engineering Course (https://neat.aicte-india.org/course-details/NEAT2020627_PROD_1)
4. Electric Vehicles (https://www.aicte-india.org/sites/default/files/Model_Curriculum/fINAL%20-%20NEP%202020%20Model%20Syllabus%20for%20Open%20Electives%20in%20Electric%20Vehicles.pdf)

Skill Development Activities Suggested

1. Simulate the electric vehicle in MATLAB/SCILAB modules

Course outcome (Course Skill Set)

At the end of the course the student will be able to:

Sl. No.	Description	Blooms Level
CO1	Explain the basics of electric and hybrid electric vehicles, their architecture, technologies andfundamentals.	1
CO2	Explain the use of different energy storage devices used for hybrid electric vehicles, theirtechnologies and control and select appropriate technology	2
CO3	Interpret working of different configurations of electric vehicles and its components, hybridvehicle configuration, performance analysis and Energy Management strategies in HEVs.	4

Program Outcome of this course

Sl. No.	Description	POs
1	An ability to independently carry out research/investigation and development work to solve practical problems.	1
2	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program.	3

Program Outcome of this course

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5
CO1	**1**		**1**		
CO2	**1**		**1**		
CO3	**1**		**1**		

Note : High - 1, Medium – 2, and Low – 3