Cummins College of Engineering for Women

(An autonomous institute affiliated to Savitribai Phule pune university)

Karve Nagar, Pune - 411 052.

Vision

To be globally renowned engineering institute for imparting holistic education and developing professional women leaders in engineering and technology

Syllabus Structure and Syllabus

of

T. Y. B. Tech.
(Mechanical Engineering)

2023 Pattern [R0]

List of Abbreviations

Abbreviation	Title
PCC	Programme Core Course
BSC	Basic Science Course
ESC	Engineering Science Course
PE	Programme Elective Course
OE	Open Elective
VSEC	Vocational and Skill Enhancement Course
CC	Co-curricular Courses / Liberal Learning Course
IKS	Indian Knowledge System
VEC	Value Education Course
RM	Research Methodology
INTR	Internship
PROJ	Project
CEP	Community Engagement Project
RM	Research Methodology
Mm	Multidisciplinary Minor
AEC	Ability Enhancement course

Autonomous Program Structure

Third Year B .Tech.
Sixth Semester (Mechanical Engineering)
Academic Year: 2025-26 Onwards

Course Code	Course Title	Teaching Scheme Hours / Week			Cr	Examination Scheme			Total Marks
		L	T	P		ISE	ESE	Pr/Or	
23PCME601	Applied Thermodynamics	3	0	0	3	50	50	-	100
23PCME602	Mechanical Vibrations	3	0	0	3	50	50	-	100
23PCME603	Industrial Engineering and Operations Research	2	0	0	2	25	25	-	50
23PCME604	Robotics and Control Systems	3	0	0	3	50	50	-	100
23PECME601	Programme Elective-II*	3	0	0	3	50	50	-	100
23MDm601	Business Analytics	3	0	0	3	50	50	-	100
23PCME601L	Applied Thermodynamics Laboratory	0	0	2	1	25	-	25	50
23PCME602L	Mechanical Vibrations Laboratory	0	0	2	1	25	-	25	50
23PECME601L	Programme Elective –II Laboratory	0	0	2	1	25	-	25	50
23VSECME601L	Robotics and Computational Methods Laboratory.	0	0	4	2	25	-	25	50
Total		**17**	**00**	**10**	**22**	**375**	**275**	**100**	**750**

L-Lecture, T=Tutorial, P= Practical, Cr= Credits, ISE =In Semester Evaluation, ESE =End Semester Examination, Pr/Or= Practical/Oral.

***Programme Elective-II**	
23PECME601A	Finite Element Analysis
23PECME601B	Powertrain Design
23PECME601C	Mechanics of Composite Materials
23PECME601D	EV Traction Systems

APPROVED BY
Secretary Academic Council
MKSSS's Cummins College of Engineering For Women, Pune-411052

APPROVED BY
Chairman Academic Council
MKSSS's Cummins College of Engineering For Women, Pune-411052

CUMMINS COLLEGE OF ENGINEERING FOR WOMEN KARVE NAGAR, PUNE-411052

Course Name	Applied Thermodynamics	L	T	P
Code Code	23PCME601	3	-	-
Pre-requisites	Engineering Thermodynamics, Fluid Mechanics, Heat Transfer			

Course Objectives: The course prepares students to,

1. Understand the working principle of reciprocating air compressor and analyze its performance parameters.
2. Understand and analyze refrigeration cycles
3. Understand and analyze various psychrometric processes
4. Understand I C Engine cycles and analyze its performance parameters
5. Understand and analyze the performance parameters of gas turbines.

Course Outcomes: Students will be able to

1. Explain the working principle and determine the performance parameters of the air compressor.
2. Analyze the refrigeration cycles and calculate COP."
3. Apply psychrometric concepts to perform air conditioning load calculations.
4. Determine the performance parameters of I C Engines and comprehend the I C Engine Cycles
5. Analyze the performance of Brayton cycle and determine the effect of reheating, intercooling and regeneration on the cycle performance

Unit:- 1	Reciprocating and Screw Air Compressors

Construction and Working principle of reciprocating and screw air compressors, performance parameters, multi-staging of a reciprocating air compressor, and capacity control of the compressor

Unit:- 2	Refrigeration: Reversed Carnot cycle, vapour compression cycle

Effect of liquid sub cooling and suction superheat, vapour absorption cycle: LiBr- H_2O system, Maximum COP, refrigerants: Natural refrigerants, properties, Compressors

Unit:- 3	Psychrometry

Basic concepts and definitions, psychrometric chart, analysis of various psychrometric processes, air conditioning load estimation, and indoor air quality considerations.

Unit:- 4	Internal Combustion Engines

Fuel air cycle, actual cycle, combustion in SI engine, testing and performance of IC engines.

Unit:- 5	Gas Turbines

Brayton Cycle, thermal Efficiency, Work ratio, inter-cooling, Reheating, and Regeneration cycle.

Text Books:

1	S. Domkundwar, C.P. Kothandaraman, A. Domkundwar, Thermal Engineering, Dhanpat Rai & Co.

Reference Books:

1	Arora C.P. Refrigeration and Air Conditioning, Tata McGraw-Hill.
2	Manohar Prasad, Refrigeration and Air Conditioning, Wiley Eastern Ltd
3	V. Ganeshan, Internal Combustion Engines, McGraw Hill.
4	V. Ganeshan, Gas Turbines, McGraw-Hill

Course Name	Mechanical Vibrations	L	T	P
Code Code	23PCME602	3	-	-
Pre-requisites	Analysis and Synthesis of Mechanisms, Machine Design			

Course Objectives: The course prepares students to

1. To understand the methods to find natural frequency of system subjected to undamped free vibrations
2. To analyze the system subjected to vibrations with viscous/coulomb damping
3. Derive Equations of Motion of MDOF system using Newton's and Lagrange's method
4. To determine natural frequencies and mode shapes of multiple degree of freedom system
5. To explain the features and applications of various dynamic modeling techniques

Course Outcomes: Students will be able to

1. Identify the fundamental elements of vibratory systems and model simple mechanical systems into their equivalent linear or torsional representations.
2. Determine the natural frequency of undamped SDOF systems using equilibrium and energy methods, and analyze the forced response to harmonic excitations (unbalance, base motion) using concepts of magnification factor and transmissibility.
3. Classify and characterize the behaviour of viscously damped SDOF systems (over, under, critically damped) in free and forced vibration.
4. Formulate the equations of motion for undamped MDOF systems using Newton's and Lagrange's methods, and compute their natural frequencies and mode shapes.
5. Simulate the dynamic response of SDOF systems to standard inputs using state-space models and software tools, and interpret results.

Unit:- 1 — **Fundamentals of Dynamic Systems**

Elements of a vibratory system, S.H.M., degrees of freedom, modeling of a system, concept of linear and non-linear systems, equivalent spring, linear and torsional systems. Matrix Algebra

Unit:- 2 — **Single Degree of Freedom Systems: Undamped**

Undamped Free and Forced Vibrations: Natural frequency by equilibrium and energy methods for longitudinal and torsional vibrations. Forced vibrations of longitudinal and torsional systems, simple harmonic excitation, excitation due to reciprocating and rotating unbalance, base excitation, magnification factor and phase difference, force and motion transmissibility

Unit:- 3 — **Single Degree of Freedom Systems: Damped**

Damped Free and Forced Vibrations: Different types of damping include free vibrations with viscous damping, as well as over-damped, critically damped, and under-damped systems, and dry friction damping.

Unit:- 4 — **Multiple Degree of Freedom Systems**

Undamped Vibrations: Free vibration of spring-coupled systems – longitudinal and torsional, Equations of Motion of MDOF system using Newton's and Lagrange's method, natural frequencies and mode shapes. Eigenvalues and Eigenvectors by Matrix Method, Introduction to Modal Analysis.

Unit:- 5 — **Dynamic Modeling and Simulation**

Digital and Fast Fourier Transform, Frequency Response of first and second order Systems, Introduction to Laplace Method for Step input, impulse input to SDOF, Laplace Transform, State Space system, Simulations using MATLAB and SIMULINK, Base Excitation, Rotating Imbalance

Text Books:

1	Daniel J. Inman, "Engineering Vibrations", Pearson Education, latest edition.
2	Rao S. S., "Mechanical Vibrations", Pearson Education Inc. Dorling Kindersley (India) Pvt. Ltd.
Reference Books:	
1	William J. Palm III, Modeling, Analysis, and Control of Dynamic Systems, Wiley,latest edition
2	Grover G. K., Mechanical Vibrations, Nem Chand and Bros.
3	Thomson, W. T., „Theory of Vibration with Applications", CBS Publishers and Distributors
4	V P Singh,Mechanical Vibrations, Dhanpat Rai & Sons.
5	Kelly S. G.,Mechanical Vibrations, Schaum„s outlines, Tata McGraw Hill Publishing Co. Ltd.
6	Meirovitch, Elements of Mechanical Vibrations, McGraw Hill.
7	M.L.Munjal, Noise and vibration control, Cambridge University Press India Private Limited.
8	Bies, D. and Hansen, C., Engineering Noise Control - Theory and Practice, Taylor and Francis.

Course Name	Industrial Engineering & Operations Research	L	T	P
Code Code	23PCME603	2	-	-
Pre-requisites				

Course Objectives: The course prepares students to

1. Effectively explain production planning and Control functions.
2. Understand different types of analysis using industrial engineering techniques viz. Method Study and Work Measurements
3. Develop mathematical skills to analyse Project Scheduling arising from a wide range of applications
4. Understand procedure for Replacement and Queuing System analysis

Course Outcomes: Students will be able to

1. Analyze different types of production planning functions viz. productivity analysis Aggregate and Capacity production planning, forecasting, inventory control
2. Apply method study and work measurements technique to solve industrial problem
3. Analyze the given Project for optimum schedule and sequence
4. Analyze the given industrial situation to optimize replacement decision and queuing problem

Unit:- 1 Productivity and PPC

Productivity Analysis: Definition, Factors, models and index (numerical);
Productivity improvement: Techniques, Lean Thinking, Value Stream Mapping (VSM);
Production Planning and Control: Functions of PPC, ERP.

Unit:- 2 Production Forecasting, Layout and Inventory Planning, Forecasting Techniques

Qualitative and Quantitative Methods: Causal and time series models, moving average, exponential smoothing, trend and seasonality (Numerical), Layout: Types of layouts
Inventory Control: Classification, ABC/FSN/VED analysis, Inventory costs, Concepts of reorder point, safety stock , Deterministic models - Concept of EOQ, EPQ, purchase model, quantity discounts shortages (Numerical), MRP.

Unit:- 3 Method Study and Work Measurements

Method Study: Definition, objective and procedural steps; activity recording tools, Human factors considerations; Value Engineering,
Work measurement: Definition, objectives and techniques: Time study & Work sampling, (numerical); Synthetic motion studies: PMTS and MTM, MOST.

Unit:- 4 Project Scheduling

CPM, Network Diagram; PERT: (Numerical), Crashing, Jobs Sequencing: N- Jobs & 2 / 3 Machines Jobs Assignment; Replacement System analysis: Replacement analysis: Maintenance cost increases with time and the value of money remains same / increases during the period; replacement of items that fail completely and suddenly

Text Books:

1	Introduction to Work Study by ILO, ISBN 978-81-204-1718-2, Oxford & IBH
2	Most Work Measurement Systems, Zandin K.B, ISBN 0824709535, CRC Press, 2002.
3	Industrial engineering and management by O. P. Khanna, Dhanpatrai publication
4	Operations Research, Prem Kumar Gupta and D S Hira, S Chand in publication 2007.

Reference Books:

1	Industrial Engineering and Operations Management, Martend Telsang, S. Chand Publication
2	Industrial Organisation & Engineering Economics by Banga and Sharma, Khanna publication
3	Operations Research: Theory And Application, J. K. Sharma, Laxmi pub. India.
4	Industrial Engineering Hand Book, H.B. Maynard, KJell, Maynard, McGraw Hill, Education, 2001

Course Name	Robotics and Control Systems	L	T	P
Code Code	**23PCME604**	**3**	**-**	**-**
Pre-requisites	Physics, Engineering Mathematics, Engineering Mechanics			

Course Objectives: The course prepares students to

1. To introduce students to foundational concepts, classifications, and a thorough understanding of kinematics, dynamics, and trajectory planning for robotic manipulators and mobile robots.
2. To familiarize students with various sensors, actuators, and perception systems integral to robotic platforms.
3. To impart knowledge of classical and modern control techniques applied in robot motion and automation.
4. To facilitate various Robot simulation tools and techniques.
5. To develop students' abilities to integrate robotics technologies in practical scenarios, foster team-based problem solving, and become aware of emerging trends in robotics and control.

Course Outcomes: Students will be able to

1. Apply homogeneous transformations to solve forward and inverse kinematics problems for robotic manipulators
2. Design sensor-actuator systems with appropriate control interfaces for robotic perception and motion control.
3. Analyze and design control systems (PID and advanced controllers) for stable robotic operation using mathematical models.
4. Evaluate robotic systems through simulation using ROS, MATLAB, and physics engines for gait analysis and validation.
5. Integrate robotic systems with emerging technologies (AI/IoT) for industrial automation and evaluate their performance through case studies

Unit:- 1	Kinematics and Dynamics of Robots

Robot definition, Laws, Classfication, Robot-Subsystems, DoF, Workspace, Payload, Performance measurement.
Forward kinematics: Transformations, D-H Parameters, 2 & 3 link planar arm(RP, RRR), SCARA, Spherical ,Stanford Robot arm.
Inverse kinematics: Position and orientation analysis, solution strategies.Differential kinematics and Jacobian: velocity, singularities..

Unit:- 2	Sensors, Actuators, and Robot Perception

Types of actuators: DC, Stepper & Servo motors, Speed-Torque characteristics, hydraulic/pneumatic actuators. Motor drive systems: speed control techniques, torque characteristics. Grippers
Sensor systems: Selection & classification, Position, Velocity, Force sensors. Robot Vision & image processing. Signal conditioning and interfacing: A/D, D/A, Sampling.

Unit:- 3	Control Systems

Introduction -Open-loop and Closed-loop control. Mathematical modeling of mechanical systems, Transfer function, Block diagram reduction techniques, SFG.
Classic controllers: P, PI, PD, PID controllers—design and tuning.Stability analysis.
Control implementation Case studies, digital control (microcontrollers, PLCs).

Unit:- 4	Robot Simulation Framework

Introduction to MATLAB Robot Toolbox, Robot Programming: VAL, Robot localisation techniques, SLAM,Motion control and Manipulation Programming. Robot Localization & Mapping: Transformation Tree,Open-source Robot simulation tools (Gazebo), Robot Operating System (ROS).		
Unit:- 5	**Applications, Integration, and Emerging Trends**	
Industrial robotics and automation: Robot cell design, PLC Programming & Robot control, integration with IoT/AI. Case Study-Industrial Robot, Quadruped RoboT and Dobot Magician manipulator.		

Text Books:	
1	Dr. S.K.Saha, "Introduction to Robotics", 3rd Edition,
2	Ogata "Robot Modeling and Control"
Reference Books:	
1	Introduction to Autonomous Robots, Nikolaus Correll et al.
2	Robotics: Vision, Manipulation and Sensors, B. Siciliano and O. Khatib
3	Probabilistic Robotics, Sebastian Thrun, Wolfram Burgard, and Dieter Fox
4	Feedback Control of Dynamic Systems, Gene Franklin, J. David Powell, and Abbas Emami-Naeini
5	Introduction to Robot Kinematics , John J. Craig,,2nd Edition
6	Mark W. Spong, Seth Hutchinson, and M. Vidyasagar
7	Robotics: Fundamental Concepts and Analysis, Ashitava Ghosal.

Course Name	**Finite Element Analysis**	**L**	**T**	**P**
Code Code	**23PECME601A**	**3**	**-**	**-**
Pre-requisites	Engineering Mechanics, Strength of Materials, Basic programming, Computer Aided Engineering			

Course Objectives: The course prepares students to

1. Introduce the foundational principles of the finite element method and develop the ability to model basic structural problems using 1D and 2D elements
2. Develop student proficiency in isoparametric formulation and the use of numerical integration techniques such as Gauss quadrature for finite element computations
3. Enable students to construct finite element models for heat transfer applications, including transient heat conduction and two-dimensional heat transfer problems.
4. Provide understanding of structural dynamics within the finite element framework, enabling students to compute natural frequencies and mode shapes of engineering structures.
5. Familiarize students with the fundamentals of nonlinear finite element analysis, with emphasis on distinguishing geometric, material, and contact nonlinearities.

Course Outcomes: Students will be able to

1. Apply finite element procedures to solve basic structural problems using 1D and 2D elements.
2. Perform numerical integration using Gauss quadrature for isoparametric elements.
3. Formulate finite element models for transient heat conduction and 2D heat transfer problems
4. Evaluate natural frequencies and mode shapes of structures using finite element models.
5. Differentiate between geometric, material, and contact nonlinearities in FEA.

Unit:- 1	**Introduction to Finite Element Method**

Review of solid mechanics and governing differential equations, concept of discretization, elements, nodes, and degrees of freedom, steps in finite element formulation, 1D element formulations including bar, truss, and beam elements, shape functions and stiffness matrix derivation, 2D element formulations including CST and LST elements for plane stress, plane strain, and axisymmetric problems, assembly of the global stiffness matrix, applications to basic structural problems such as axial, bending, and torsional analysis.

Unit:- 2	**Isoparametric Formulation and Numerical Integration**

Concept of natural coordinate systems, shape functions for 1D and 2D isoparametric elements, Jacobian matrix and its significance, strain–displacement matrix formulation, numerical integration using Gauss quadrature, Gauss points and weighting coefficients, application of numerical integration to stiffness matrix evaluation, convergence requirements, patch test, and element quality considerations.

Unit:- 3	**Finite Element Applications in Heat Transfer**

Governing equations of heat conduction, finite element formulation for 1D steady-state heat conduction, transient heat conduction with explicit and implicit time integration methods, lumped and consistent heat capacity matrices, 2D heat transfer formulation using isoparametric elements, implementation of convection and radiation boundary conditions, example problems and numerical considerations in heat transfer analysis.

Unit:- 4	**Structural Dynamics using Finite Elements**

Review of vibration fundamentals, derivation of equations of motion for discrete systems, formulation of lumped and consistent mass matrices and damping matrices, eigenvalue problems in structural dynamics, determination of natural frequencies and mode shapes using finite element models, basics of harmonic and transient analysis		
Unit:- 5	**Introduction to Nonlinear Finite Element Analysis**	
Sources of nonlinearity in structural systems, geometric nonlinearity involving large displacements and rotations with updated and total Lagrangian formulations (conceptual), material nonlinearity including elastic–plastic behavior, yielding, hardening, and viscoelastic/viscoplastic models, contact nonlinearity involving contact constraints, gap functions, penalty and Lagrange multiplier methods, iterative solution techniques such as Newton–Raphson method, convergence issues, and industrial case studies demonstrating nonlinear FEA applications.		

Text Books:

1	Daryl Logan, A First Course in the Finite Element Method, Cengage Learning India Pvt. Ltd., 6th Edition 201
2	Seshu P., Textbook of Finite Element Analysis, PHI Learning Private Ltd. New Delhi, 2010

Reference Books:

1	Gokhale N. S., Deshpande S. S., Bedekar S. V. and Thite A. N., Practical Finite Element Analysis, Finite to Infinite, Pune
2	J. N. Reddy, An Introduction to the Finite Element Method, Tata McGraw Hill, 2003
3	Chandrupatla T. R. and Belegunda A. D. -Introduction to Finite Elements in Engineering Prentice Hall India

<table>
<tr><td>Course Name</td><td>Powertrain Design</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Code Code</td><td>23PECME601B</td><td>3</td><td>-</td><td>-</td></tr>
<tr><td>Pre-requisites</td><td>Strength of machine elements, Machine Design</td><td colspan="3"></td></tr>
<tr><td colspan="5">Course Objectives: The course prepares students to</td></tr>
<tr><td colspan="5">1. Analyze, select, and design mechanical power transmission elements, including gear drives and flexible belts, for automotive applications using standard methodologies and manufacturers' catalogues.
2. Select appropriate rotational support and management systems, including bearings, seals, and lubrication systems, based on load, life, and operational reliability requirements for transmission assemblies.
3. Analyze the power flow and operational principles of conventional (MT, AT, DCT, CVT) and hybrid (MHEV, FHEV) transmission systems.
4. Analyze electrified powertrain architectures (Series, Parallel, Power-Split, BEV) by integrating motor characteristics with transmission systems.
5. Evaluate powertrain systems from a holistic engineering perspective, including control strategies, system integration and sustainability.</td></tr>
<tr><td colspan="5">Course Outcomes: Students will be able to</td></tr>
<tr><td colspan="5">1. Apply AGMA design principles to calculate gear tooth dimensions and dynamic loads, and analyze failure modes for a given mechanical power transmission application.
2. Design a flexible drive by analysing the tensions and stresses, for the required application.
3. Evaluate bearing requirements for a given load and speed condition to select an appropriate bearing from manufacturer catalogues, and predict its operational life using standard load-life relationships.
4. Elaborate the characteristics, constructional-operational features and applications of various transmission systems to select a suitable system.
5. Compare various electrified powertrain system architectures, control modules, energy management systems with sustainability perspective.</td></tr>
<tr><td>Unit:- 1</td><td colspan="4">Mechanical Power Transmission Elements:</td></tr>
<tr><td colspan="5">Gear Classification & Tooth Systems Types, involute profile, pressure angle, module/diametric pitch Gear Force Analysis & Failure Modes, Bending, and pitting, scuffing, gear tooth failure modes, AGMA Gear Design & Dynamic Loading, Strength equations, dynamic factor, and application examples, Planetary Gear Sets & Applications, Kinematics, torque ratios, hybrid/EV applications , Transmission Shift Mechanisms, Synchronizers, dog clutches, shift quality, Flexible Drives: Belts & Chains, Power ratings, tension ratios, manufacturer selection</td></tr>
<tr><td>Unit:- 2</td><td colspan="4">Rotational Support Systems:</td></tr>
<tr><td colspan="5">Bearing Classification & Selection, Rolling vs. sliding, bearing types, application factors, Bearing Ratings & Life Calculation, Static/dynamic load ratings, life, equivalent load, Bearing Reliability & Failure Analysis, Weibull statistics, failure modes, lubrication effects, Practical Bearing Selection, Manufacturer catalogue navigation, mounting arrangements</td></tr>
<tr><td>Unit:- 3</td><td colspan="4">Transmission Systems:</td></tr>
<tr><td colspan="5">Transmission Requirements & Engine Matching Vehicle requirements, engine maps, gear ratio selection, Torque Converters, Fluid coupling principles, torque multiplication, Manual Transmissions (MT), Constant mesh, synchromesh, shift mechanisms, Automatic Transmissions (AT) Planetary gear sets, hydraulic control, shift scheduling, CVT & DCT Technologies,</td></tr>
<tr><td>Unit:- 4</td><td colspan="4">Electrified Powertrains:</td></tr>
</table>

Electric Motor Fundamentals, Torque production, four-quadrant operation, Motor Types & Characteristics, PMSM, Induction, SRM comparison, efficiency maps, Series & Parallel Hybrid Architectures, Power-Split Hybrid Systems, Planetary power-split devices, Toyota/ GM systems, System Sizing: Motor & Gearbox, Performance requirements, gear ratio optimization, EV Transmission Design, Reduction gear design, multi-speed considerations, Battery System Fundamentals, Cell types, pack architecture, thermal management.		
Unit:- 5	**Controls & Future Trends:**	
Powertrain Control Modules (PCM/TCM), Hierarchical control, actuator control, Transmission Control Strategies, Shift scheduling, adaptive learning, shift quality, Hybrid Energy Management, Thermal Management Systems, Cooling strategies for battery/motor/power electronics, Sustainability & Lifecycle Analysis, Well-to-wheel emissions, recycling, material impact.		

Text Books:

1	Bhandari V.B, "Design of Machine Elements", Tata McGraw Hill Publication Co. Ltd.
2	Robert Fischer, Ferit Küçükay, Gunter Jürgens, Rolf Najork, Burkhard Pollak, "The Automotive Transmission", Springer Publication
3	Iqbal Husain, "Electric and Hybrid Vehicles, Design Fundamentals", CRC PRESS.

Reference Books:

1	Shigley J.E. and Mischke C.R., "Mechanical Engineering Design", McGraw Hill Publication Co. Ltd
2	Spotts M.F. and Shoup T.E., "Design of Machine Elements" ,Prentice Hall International.
3	Willium C. Orthwein,"Machine Components Design",West Publishing Co. and Jaico Publications House.
4	"Design Data",P.S.G. College of Technology, Coimbatore.
5	Juvinal R.C,"Fundamentals of Machine Components Design",John Wiley and Sons.
6	Hall A.S., Holowenko A.R. and Laughlin H.G, "Theory and Problems of Machine Design" , Schaum"s Outline Series.
7	Michael Nikowitz, "Advanced Hybrid and Electric Vehicles, System Optimization and Vehicle Integration", Springer International Publishing Switzerland 2016.
8	Amir Khajepour, Saber Fallah, Avesta Goodarzi , "Electric and Hybrid Vehicles: Technologies, Modeling and Control - A Mechatronic Approach", Wiley Publication.

Course Name	**Mechanics of Composite Materials**	**L**	**T**	**P**
Course Code	**23PECME601C**	**3**	**-**	**-**
Pre-requisites	Engineering Mechanics, Strength of Materials, Engineering Metallurgy			

Course Objectives: The course prepares students to

1. Understand a perspective utilization and processing of composite materials
2. Micro and macro mechanical analysis of the composite material at lamina level
3. Analyze the laminated composite material at macro level
4. Understand testing methods of composite materials to evaluate mechanical properties

Course Outcomes: Students will be able to

1. Classify composite materials, their constituents (fibers, matrices, additives), and relate their fundamental characteristics to engineering applications.
2. Select and describe appropriate manufacturing processes (open/closed mould) for thermoset and thermoplastic polymer matrix composites (PMCs) based on their principles and parameters.
3. Evaluate the elastic moduli and predict the strength of a unidirectional lamina using micromechanics and apply macromechanical analysis with failure criteria to an angled ply.
4. Analyze the elastic response (in-plane and flexural) of multi-directional laminates using Classical Lamination Theory (CLT) and laminate code notation.
5. Apply standard test methods to characterize key mechanical properties (tensile, flexural, shear, impact) of composite materials and interpret the results.

Unit:- 1 Introduction to composites

Introduction to advanced materials and types, Definition, General Characteristics, Applications, Fibers, Types of fibers, Mechanical Properties of fibers; Matrix, Types of matrix, Polymer Matrix- Thermoset and Thermoplastic, Fillers/Additives/Modifiers of Fiber Reinforced Composites

Unit:- 2 Manufacturing of composites

Fabrication process for thermoset and thermoplastic PMC, open mould process as hand layup techniques; structural laminate bag molding, production procedures for bag molding; filament winding, and Closed mould process as pultrusion, performing, thermo-forming, injection molding, blow molding, Process parameters.

Unit:- 3 Elastic and strength Behaviour of Lamina

Micromechanical Analysis of Lamina: Introduction, Volume and mass fraction, density, void content, evaluation of elastic moduli, ultimate strength of unidirectional lamina

Macro-mechanical Analysis of Lamina: Review and definition of stress, strain and Elastic Moduli, Hooke's Law for different types of materials, Hook's law for 2D unidirectional and angular lamina, engineering constants of an angle lamina, Strength failure theories of an angle lamina

Unit:- 4 Elastic Behaviour of Laminate

Introduction to Laminate Code, Strain-displacement relations, Stress-strain relation for a laminate, force and moment resultants related to mid plane strains and curvatures, In-Plane engineering constants of a laminate, Flexural engineering constants of a laminate

Unit:- 5 Testing of Composites

Societies for Testing Standards, Background to Mechanical Testing of Composites, Test Method and analysis of Tensile Properties, Compressive Properties, Flexural Properties, In-Plane Shear Properties, Inter-laminar Shear Strength properties, Impact Properties.

Text Books:

1	Autar K. Kaw, "Mechanics of Composite Materials", CRC Press, Taylor & Francis Group, 2012.
Reference Books:	
1	Robert M. Jones, "Mechanics of Composite Materials" 2nd Edition, CRC Press 1998.
2	Isaac M. Daniels, OriIshai, "Engineering Mechanics of Composite Materials", Oxford University Press, 2010.
3	Madhujit Mukhopadhyay, "Mechanics of Composite Materials and Structures", University Press, 2004.

<table>
<tr><td>Course Name</td><td>EV Traction Systems</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Code Code</td><td>23PECME601D</td><td>3</td><td>-</td><td>-</td></tr>
<tr><td>Pre-requisites</td><td>Theory of Machines, Basics of Electrical Engineering</td><td colspan="3"></td></tr>
<tr><td colspan="5">Course Objectives: The course prepares students to</td></tr>
<tr><td colspan="5">1. Size an electric traction motor and inverter based on vehicle performance targets (e.g., 0-60 mph, gradeability, top speed).
2. Compare and select appropriate motor technologies (PMSM, IM, SRM) for given application segments (passenger car, commercial vehicle, performance EV).
3. Design a foundational motor control strategy using industry-standard scalar and vector control techniques.
4. Analyze and specify the key components of a modern e-powertrain, including power electronics, gearbox, and thermal management system.
5. Simulate, test, and validate a virtual powertrain model against performance, efficiency, and regulatory standards.</td></tr>
<tr><td colspan="5">Course Outcomes: Students will be able to</td></tr>
<tr><td colspan="5">1. Analyze and select appropriate traction motors based on EV performance requirements and operational characteristics
2. Design the power electronic conversion chain for controlling traction motor speed and torque
3. Evaluate and design EV transmission and drivetrain layouts for optimal vehicle performance and packaging
4. Implement control strategies for traction motors and integrate them with vehicle dynamics systems
5. Evaluate the performance of an integrated traction system and assess emerging technological trends</td></tr>
<tr><td>Unit:- 1</td><td colspan="4">Traction Fundamentals</td></tr>
<tr><td colspan="5">Torque-Speed-Power characteristics for traction. Motor Types : Permanent Magnet Synchronous Motor (PMSM), Induction Motor (IM), Switched Reluctance Motor (SRM). Comparative analysis: cost, efficiency, performance, robustness. Motor Sizing Fundamentals: Peak vs. continuous power, torque requirements for launch and gradability. Efficiency Mapping: Understanding loss mechanisms (copper, iron, stray) and high-efficiency regions. Case Studies: Motor choices in Tesla, Nissan Leaf , Audi e-tron.</td></tr>
<tr><td>Unit:- 2</td><td colspan="4">Power Electronics for Traction</td></tr>
<tr><td colspan="5">Traction Inverter Topology: IGBTs, SiC MOSFETs. Importance of switching frequency and losses. Pulse Width Modulation (PWM) Techniques: SPWM, SVPWM for optimal DC-AC conversion. DC-DC Converters in Traction: Role of the auxiliary DC-DC converter and the high-voltage bi-directional converter (for regenerative braking). Gate Driver Circuits & Protection: Isolation, de-saturation detection, overcurrent protection. Thermal Management of Power Electronics: Cooling plate design, liquid cold plates</td></tr>
<tr><td>Unit:- 3</td><td colspan="4">Transmission & Drivetrain Configurations</td></tr>
<tr><td colspan="5">The Need for Gearing in EVs: Single-speed reducers vs. multi-speed transmissions. Gearbox Design for EVs: Helical vs. planetary gear sets, noise-vibration-harshness (NVH) considerations. Drivetrain Architectures: Central motor drive, e-Axle (integrated drive unit), wheel-hub motors, and distributed drive. Differentials and Torque Vectoring: Open vs. electronic locking diffs. Active torque vectoring for stability and performance. Component Integration: Motor-inverter-gearbox packaging challenges and solutions.</td></tr>
<tr><td>Unit:- 4</td><td colspan="4">Traction Motor Control</td></tr>
</table>

Theory: Field-Oriented Control (FOC / Vector Control) for PMSM and IM. Direct Torque Control (DTC). Regenerative Braking Coordination: Blending regenerative and friction brake torque. Interaction with ESP/ABS systems. Traction Control System (TCS) for EVs: Preventing wheel slip using precise motor torque control. Drivability Tuning: Shaping torque response for different drive modes.		
Unit:- 5	**System Integration, Testing & Future Trends**	
Traction System Efficiency Analysis: Mapping losses from battery terminals to wheels. Durability & Reliability: Standards (ISO, IEC), vibration testing, thermal cycling. NVH in EV Traction Systems: Motor whine, gear noise, inverter switching frequency audible noise, and mitigation. Testing & Validation: Dyno testing, HIL (Hardware-in-Loop) setups for traction control. Future Trends: In-wheel motor advancements, wireless charging integration with drive, axial flux motors, and the role of Vehicle-to-Grid (V2G) in traction system design.		

Text Books:	
1	Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles, John G. Hayes & A. Goodarzi..
2	Design of Rotating Electrical Machines, Juha Pyrhönen, Tapani Jokinen, Valéria Hrabovcová.
Reference Books:	
1	Vyas, N.B., Seth, R.K., Vora, K.C. Fundamentals of Electric Vehicles: Technology & Economics. Notion Press. (Indian Context)
2	Larminie, James, and Lowry, John. Electric Vehicle Technology Explained. Wiley.
3	Modern Power Electronics and AC Drive, Bimal K Bose

Course Name	Business Analytics	L	T	P
Code Code	23MDm601	3	-	-
Pre-requisites	Statistics and Probability, Programming Fundamentals			

Course Objectives: The course prepares students to

1. Understand the foundational concepts of business analytics and its role in driving data-informed decision-making across various industries.
2. Develop proficiency in using statistical methods and data wrangling techniques to prepare and explore datasets.
3. Apply predictive modeling techniques to solve classification, regression, and clustering problems
4. Design and interpret data dashboards for effective business communication and storytelling
5. Evaluate the ethical implications, challenges, and future trends of business analytics in a real-world context.

Course Outcomes: Students will be able to

1. Differentiate between descriptive, predictive, and prescriptive analytics and their business applications
2. Prepare and explore raw datasets for analysis by applying data cleaning, transformation, and exploratory data analysis (EDA) techniques.
3. Construct predictive models for classification and regression using machine learning algorithms and evaluate their performance.
4. Design interactive dashboards to visualize key performance indicators (KPIs) and communicate actionable insights to stakeholders.
5. Analyze a business problem to propose a structured analytics solution, considering the end-to-end data lifecycle.

Unit:- 1	Introduction to Business Analytics:

The Data-Driven Enterprise Analytics Taxonomy: Descriptive, Diagnostic, Predictive, Prescriptive The Analytics Process (CRISP-DM): Business Understanding, Data Understanding, Data Preparation, Modeling, Evaluation, Deployment. Key Concepts: Data Sources, Big Data (Volume, Velocity, Variety, Veracity).

Unit:- 2	Data Processing and Exploratory Data Analysis (EDA)

Data Acquisition & Cleaning: Handling missing values, outliers, and inconsistent data entries. Data Transformation: Feature scaling, normalization, creating derived variables (e.g., Binning, Dummy Variables). Data Exploration & Visualization: Univariate Analysis: Summary statistics, distributions (histograms, box plots). Bivariate Analysis: Correlation analysis, scatter plots, cross-tabulations. Introduction to Tools: Performing EDA using Python (Pandas, Matplotlib, Seaborn) or R.

Unit:- 3	Supervised Learning for Predictive Analytics

Regression models: Linear, Polynomial, Ridge/Lasso for parameter prediction, Classification: Logistic Regression, Decision Trees, Random Forest for defect classification, Predictive Maintenance (PdM): Remaining Useful Life (RUL) estimation, Time-series forecasting: ARIMA, demand and failure prediction, Model evaluation: Cross-validation, confusion matrix, ROC-AUC, Hyper parameter tuning with GridSearch/RandomSearch for defect classification problems.

Unit:- 4	Data Visualization and Dashboard Design

Principles of Effective Visualization, Introduction to Dashboarding Tools: Tableau Public or Microsoft Power BI. Connecting to Data Sources, Creating Basic Visualizations: Bar charts, line graphs, maps, pie charts. Building an Interactive Dashboard: Filters, parameters, and actions. Storytelling with Data: Designing a dashboard to narrate a business story and guide decision-making.		
Unit:- 5	**Applications and Future Trends**	
Case Study Applications: Manufacturing & Quality Analytics, Real-time anomaly detection and root cause analysis, Supply Chain & Logistics for Manufacturing, Product Development & Design Analytics, Digital Twins Models from data, Autonomous Systems: Data based real-time decision making		

Text Books:

1	Business Analytics: Data Analysis & Decision Making, S. Christian Albright and Wayne L. Winston.
2	An Introduction to Statistical Learning: with Applications in Python, Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani.

Reference Books:

1	Storytelling with Data: A Data Visualization Guide for Business Professionals, Cole Nussbaumer Knaflic.

Course Name	Applied Thermodynamics Laboratory	L	T	P
Code Code	23PCME601L	-	-	2
Pre-requisites	Engineering Thermodynamics, Fluid Mechanics, Heat Transfer			

Course Objectives: The course prepares students to

1. To conduct trial and determine performance parameters for reciprocating air compressor.
2. To conduct trial and determine performance parameters for rotary screw air compressor.
3. To evaluate performance of vapor compression refrigeration cycle.
4. To analyze various psychrometric processes.
5. To conduct trial and determine performance parameters of I C Engines.

Course Outcomes: Students will be able to

1. Determine the performance parameters (volumetric, isentropic, and isothermal efficiencies) of reciprocating and rotary screw air compressors through standardized testing.
2. Evaluate the coefficient of performance (COP) of vapor compression refrigeration systems and ice plants by conducting energy audits on test rigs.
3. Analyze psychrometric processes and estimate cooling/heating capacities by performing tests on an air conditioning system.
4. Assess the performance of internal combustion engines (SI & CI) by determining brake thermal efficiency, mechanical efficiency, volumetric efficiency, and preparing heat balance sheets.
5. Compare the performance of individual cylinders and estimate engine frictional losses by conducting Morse tests on multi-cylinder engines.

Laboratory Work:

1. Performance test on two stage reciprocating air compressor to determine volumetric efficiency and isothermal efficiency.
2. Performance test on rotary screw air compressor to determine volumetric efficiency and isentropic efficiency.
3. Trial on vapor compression refrigeration test rig to determine coefficient of performance.
4. Trial on ice plant test rig to determine coefficient of performance.
5. Trial on air conditioning test rig to analyze various psychrometric processes.
6. Trial on multicylinder four stroke petrol engine to determine brake thermal efficiency, mechanical efficiency, volumetric efficiency and to prepare a heat balance sheet.
7. Trial on single cylinder four stroke Diesel engine to determine brake thermal efficiency, mechanical efficiency, volumetric efficiency and to prepare a heat balance sheet.
8. Morse test on a multi-cylinder petrol/diesel engine to determine friction power and mechanical efficiency.
9. Visit to the air conditioning plant to study vapor compression refrigeration system, air handling unit and cooling towers.

Course Name	Mechanical Vibrations Laboratory	L	T	P
Course Code	23PCME602L	0	0	2
Pre-requisite	Kinematics of Machinery, Machine Design			

Course Objectives: The course prepares students to

1. Provide hands-on experience in using computational and simulation tools for modeling and analyzing vibration problems.
2. Enable students to compute and visualize free and forced vibration responses of single-degree-of-freedom systems.
3. Introduce computational methods for evaluating natural frequencies and mode shapes of multi-degree-of-freedom systems.
4. Familiarize students with experimental investigation of vibration due to rotating imbalance and its practical implications in machinery.
5. Develop the ability to validate experimental results through comparison with analytical and numerical vibration models.

Course Outcomes: Students will be able to

1. Use computational and simulation tools to determine time response of a single-degree-of-freedom system subjected to free vibration and plot the displacement–time response.
2. Use computational and simulation tools to analyze the forced vibration response of a single-degree-of-freedom undamped system and generate displacement–time plots.
3. Determine the natural frequencies and mode shapes of a multi-degree-of-freedom system using appropriate computational techniques.
4. Perform and analyze experiments on rotating imbalance to study vibration characteristics and system response.
5. Correlate experimental vibration responses with analytical and numerical results using basic dynamic modeling and simulation techniques.

Laboratory Work:

1. Introduction to MATLAB environment, basic functions, and plotting for vibration analysis.
2. Simulation of undamped and damped free vibration of a single-degree-of-freedom (SDOF) system using MATLAB/SIMULINK.
3. Simulation of undamped and damped forced vibration of an SDOF system using MATLAB/SIMULINK.
4. Simulation of undamped free vibration of a multi-degree-of-freedom (MDOF) system using MATLAB/SIMULINK.
5. Eigenvalue analysis and simulation of MDOF systems in MATLAB for determination of natural frequencies and mode shapes.
6. Experimental determination of damped natural frequency of an SDOF system.
7. Experimental modal analysis of a cantilever beam for identification of natural frequencies and mode shapes.
8. Experimental investigation of vibration due to rotating imbalance and analysis of system response.
9. Experimental study of wheel/rotor balancing on a computerized balancing machine.

Course Name	Finite Element Analysis Laboratory	L	T	P
Code Code	23PECME601AL	-	-	2
Pre-requisites	Engineering Mechanics, Strength of Materials, Basic programming, Computer Aided Engineering			

Course Objectives: The course prepares students to

1. Provide hands-on experience in building, analyzing, and interpreting finite element models for structural, thermal, and dynamic problems.
2. Develop the ability to apply appropriate meshing strategies, element types, boundary conditions, and solver settings using commercial FEA software.
3. Strengthen students' understanding of isoparametric formulation, numerical integration, transient simulations, and modal analysis through computational experiments.
4. Enhance the capability to analyze and validate FEA results by comparing numerical outcomes with analytical solutions or benchmark cases.
5. Introduce students to nonlinear analysis concepts including geometric, material, and contact nonlinearities through simplified simulation exercises.

Course Outcomes: Students will be able to

1. Develop finite element models for basic structural components using 1D, 2D, and 3D elements in commercial FEA software
2. Perform numerical integration using Gauss quadrature and validate element matrices through simple coding or software-based tools
3. Simulate transient and steady-state heat transfer problems and interpret temperature distribution and heat flux results
4. Conduct modal analysis to extract natural frequencies and mode shapes and compare with analytical solutions where applicable
5. Demonstrate basic nonlinear FEA capabilities by distinguishing and performing analyses involving geometric, material, or contact nonlinearities

Laboratory Work:

1. A computer program for stress analysis of plane stress using the iso-parametric formulation
2. A computer program for 1-D temperature analysis for transient heat transfer problem
3. Perform stress and deflection analysis of any machine component consisting of 3-D elements using FEA software.
4. Perform modal analysis of any machine component using FEA software.
5. Perform harmonic analysis of any machine component using FEA software.
6. Perform transient analysis of any machine component using FEA software.
7. Perform temperature distribution analysis of heat transfer problem using FEA software
8. Perform Nonlinear FEA analysis to model geometry, material and contact non linearity

Course Name	Powertrain Design Laboratory	L	T	P
Code Code	23PECME601BL	-	-	2
Pre-requisites	Strength of machine elements, Machine design			

Course Objectives: The course prepares students to

1. To design a transmission system for the specified requirements
2. To analyze and validate the designed system using Ansys software.
3. Ddiscuss the final design with presentation and design report.
4. To compare the automotive transmission systems/powertrain architectures for design, performance, maintenance and cost aspects. Design a transmission system for the specified requirements.

Course Outcomes: Students will be able to

1. Design a transmission system for the specified requirements.
2. Analyze and validate the designed system using Ansys.
3. Discuss the final design with presentation and design report
4. Compare the effects of manufacturing grade and the type of gear on design of the drive and select a required drive from manufacturer's catalogue.

Lab Work:

Module A: Comprehensive Design Project (Group Project: 3-4 Students)

Project Theme: Design of a Transmission System

Milestone 1: Project Proposal & Specification: Identify a specific application. Define detailed functional requirements, performance specifications, and design constraints (size, weight, cost, efficiency, life).

Milestone 2: Conceptual Design & System Layout: Brainstorm and evaluate the possible transmission configurations (e.g., parallel shaft vs. planetary). Select the best concept. Create an initial system layout and kinematic diagram.

Milestone 3: Detailed Design & Analysis: Design all critical components (gears, shafts, keys, bearings, housing) using standard design equations (AGMA). Select all standard components (bearings, seals) from manufacturer catalogs. Create a detailed 3D CAD assembly of the entire system

Milestone 4: F.E.A. and design validation: Simulation-based validation for components post analytical design using 'Ansys Mechanical'. Introduction to advance methods for simulating gear train, belt drives etc. using 'Ansys Motion'or 'Ansys Mechanical' (Rigid body dynamics)

Milestone 5: Final Design Review & Presentation: Prepare a design report and a presentation. The presentation should justify design choices, show the final CAD models, present key analysis results, and discuss potential improvements.

Module B: Case Studies

Case studies: Comparative study of helical gear drive Vs spur gear drive, Effect of manufacturing accuracy of a gear drive on design, Selection of a bearing and flexible drive from manufacturing catalogue.

Course Name	EV: Traction Systems Laboratory	L	T	P
Code Code	23PECME601DL	-	-	2
Pre-requisites	Theory of Machines, Basics of Electrical Engineering			

Course Objectives: The course prepares students to

1. Select and characterize electric traction motors by analyzing their performance under dynamic drive cycles.
2. Design and implement real-time control strategies for electric motors using industry-standard embedded systems.
3. Integrate and validate the core components of an electric powertrain into a cohesive system
4. Model and simulate a complete EV drivetrain to predict and analyze its performance, efficiency, and energy recovery.

Course Outcomes: Students will be able to

1. Determine the operational characteristics of motors and select a suitable motor for a given application.
2. Develop and deploy control algorithms for electric drives using simulation and hardware.
3. Assemble and test key powertrain components, demonstrating their integrated function.
4. Evaluate overall powertrain performance, including regenerative braking, through system-level simulation.

Lab Work:

1. Performance Characteristics of DC/AC Motors under Various Drive Cycles (Hardware)
2. Performance Characteristics of DC/AC Motors under Various Drive Cycles (Simulations)
3. Assemble and Integrate Various Components of an EV Powertrain.
4. Control a Motor (AC/DC) with Various Control Strategies
5. Simulate Performance of Drive Train with SIMULINK/SIMMECHANICS
6. Determine Performance of Gear Trains (Epicyclic) for Different Drive Cycles.
7. Demonstration of Power Electronics Components of EV Drive Train
8. Simulation of complete power train on Ansys/Matlab.

<table>
<tr><td>Course Name</td><td>Robotics and Computational Methods Laboratory</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Code Code</td><td>23VSECME601L</td><td>-</td><td>-</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="3"></td></tr>
<tr><td colspan="5">Course Objectives: The course prepares students to</td></tr>
<tr><td colspan="5">1. Implement fundamental numerical algorithms for root-finding, solving linear systems, curve fitting, interpolation, integration, and solving ordinary differential equations using programming tools, and analyze their results to solve engineering problems.
2. Model the kinematic behavior of robotic manipulators (forward/inverse kinematics, Jacobian, workspace) and validate these models through simulation in environments such as MATLAB or Python
3. Construct functional robotic systems by integrating actuators, sensors (e.g., IR, ultrasonic, vision), and microcontrollers/PLCs, and program them to execute basic automated tasks and human-robot interactions
4. Design, simulate, and test a complete robotic solution for a defined industrial process (e.g., pick-and-place, line following) by synthesizing principles of kinematics, sensor integration, and control logic.
5. Document and communicate the design process, algorithmic approach, system integration challenges, and experimental validation of both computational and physical prototypes in a professional manner.</td></tr>
<tr><td colspan="5">Course Outcomes: Students will be able to</td></tr>
<tr><td colspan="5">1. Implement and analyze numerical methods for solving non-linear equations, systems of linear equations, and ordinary differential equations to simulate engineering systems.
2. Develop programs for curve fitting and interpolation of experimental data to model relationships between engineering parameters.
3. Apply numerical integration techniques to evaluate definite integrals for applications in areas such as area calculation and signal analysis.
4. Determine the position, velocity, and workspace of robotic manipulators by applying principles of forward and inverse kinematics and Jacobian analysis.
5. Integrate sensors (e.g., vision, proximity, encoders) with robotic platforms and program basic reactive behaviours for automation and navigation tasks.
6. Design, integrate, and validate a complete robotic system for a defined industrial or interactive task by synthesizing mechanics, electronics, and control software.</td></tr>
<tr><td colspan="5">Lab Work:</td></tr>
<tr><td colspan="5">1. Construct flowchart and develop program for finding Root of Equation: Newton Raphson Method
2. Construct flowcharts and develop programs for Simultaneous linear algebraic equations: i) Gauss elimination methods ii) Gauss Seidel method
3. Construct flowchart and develop program for Curve Fitting: i) straight line ii)power equation iii) exponential equation
4. Construct flowchart and develop program for Interpolation: Lagrange interpolation
5. Construct flowchart and develop program for Numerical Integration: i) Trapezoidal rule ii) Simpson's 1/3 rd. rule</td></tr>
</table>

6. Construct flowchart and develop program Ordinary differential equations: i) Euler's method methods ii) Classical 4th order Runge Kutta method
7. Study and demonstration of various types of robotic arms and mobile robots (hardware/virtual lab)
8. Building and configuring basic robot platforms (wheeled, arm) using kits or simulation tools.
9. Implementation and validation of forward kinematics using a physical or virtual 2/3 DOF manipulator.
10. Solving inverse kinematics problems on a simulated or real robot arm; plotting end effector paths
11. Calculation of Jacobian and analysis of singularities for 2-DOF/3-DOF arms in MATLAB or Python.
12. Workspace mapping: plotting reachable and non-reachable points for a robot
13. Interfacing and testing various sensors (IR, ultrasonic, encoders, vision, force/tactile) with a microcontroller or robotics kit.
14. Camera-based object/colour detection or simple vision-guided navigation using a robot
15. Basic automation—PLC programming to control start/stop operations or sequence of Industrial Robot operation
16. Design, simulation, and real-world test of an industrial process (pick-and-place, packaging, or spray painting) using a robot and appropriate sensors.
17. Human-robot interaction demonstration (gesture-control, voice-command, or remote control via Bluetooth/app).
18. Sensor-guided mobile robot for line/maze following or object fetching (integration).