ANNA UNIVERSITY : : CHENNAI 600 025

UNIVERSITY DEPARTMENTS

M.E. MOBILITY ENGINEERING

REGULATIONS – 2023

CHOICE BASED CREDIT SYSTEM

VISION

The Department of Mechanical Engineering strives to be recognized globally for excelling in engineering education and research leading to innovative, entrepreneurial, and competent graduates in Mechanical Engineering and allied disciplines.

MISSION

1. Providing world class education by fostering effective teaching learning process that is supported through pioneering and cutting-edge research to make impactful contribution to the society.

2. Attracting highly motivated students with enthusiasm, aptitude, and interest in the field of Mechanical and allied Engineering disciplines.

3. Expanding the frontiers of Engineering and Science in technological innovation while ensuring academic excellence and scholarly learning in a collegial environment.

4. Excelling in industrial consultancy and research leading to innovative technology development and transfer.

5. Serving the society with innovative and entrepreneurially competent graduates for the national and international community towards achieving the sustainable development goals.

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M.E MOBILITY ENGINEERING

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PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

The Mobility Engineering program seeks to prepare PG students for productive and rewarding careers in the field of mobility. The PEOs are listed below:

(i) Acquire knowledge and employability in mobility with requisite skills facilitating quick progress in graduands career

(ii) Inclination towards advanced research for mitigating the challenges in mobility systems.

(iii) Progressing as a mobility expert/entrepreneur for providing solutions towards improving the efficacy and environmental sustainability of mobility systems.

PROGRAMME OUTCOMES (POs):

PO	Programme Outcome
1	An ability to independently carry out research/investigation and development work to solve practical problems.
2	An ability to write and present a substantial technical report/document.
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the programme.
4	Technically sound and competent to work in a challenging mobility industry
5	Ability to transfer acquired knowledge through innovative and modern teaching methodologies
6	Capability to excel in core mobility research at national and international institutions / laboratories

PEO & PO Mapping

PEO	PO					
	1	2	3	4	5	6
I.	3	3	3	3	2	3
II.	3	2	3	1	1	3
III.	2	2	2	3	3	3

PROGRAMME ARTICULATION MATRIX

		COURSE NAME	PO1	PO2	PO3	PSO4	PSO5	PSO6
YEAR I	SEMESTER I	Advanced Numerical Methods	3	2	-	-	3	2
		Concepts In Electronics Engineering	3	2	-	-	3	2
		Modern Engine Technologies	3	2	-	-	3	2
		Fluid Mechanics and Heat Transfer	3	2	-	-	3	2
		Research Methodology and IPR	3	2	-	-	3	2
		Automotive Technology	3	2	-	2	2	2
		Electric Vehicle Laboratory	3	2	-	-	3	2
		Simulation Laboratory - I	3	2	-	-	3	2
	SEMESTER II	Electric Vehicle Technology	3	2	-	-	3	2
		Sensors and Data Acquisition System	3	2	-	-	3	2
		Energy Storage Technologies	3	2	-	-	3	2
		Professional Elective - I	-	-	-	-	-	-
		Professional Elective - II	-	-	-	-	-	-
		Professional Elective – III	-	-	-	-	-	-
		Simulation Laboratory - II	3	2	-	-	3	2
		Electric Vehicle Laboratory	3	2	-	-	3	2
		Summer Internship (4 Weeks)	3	3	3	3	2	3
YEAR II	SEMESTER III	Professional Elective – IV	-	-	-	-	-	-
		Professional Elective – V	-	-	-	-	-	-
		Research Data Analysis Laboratory	3	3	2	1	3	1
		Technical Seminar	1	3	1	1	2	2
		Project Work – I	3	3	3	3	3	3
	SEMESTER IV	Project Work – II	3	3	3	3	3	3

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M.E. MOBILITY ENGINEERING

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CURRICULUM AND SYLLABI FOR SEMESTER I TO IV

SEMESTER - I

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	MA3155	Advanced Numerical Methods	FC	4	0	0	4	4
2.	MR3151	Concepts in Electronics Engineering	FC	2	0	2	4	3
3.	IC3102	Modern Engine Technologies	PCC	3	0	0	3	3
4.	EY3151	Fluid Mechanics and Heat Transfer	PCC	3	1	0	4	4
5.	MB3101	Automotive Technology	PCC	4	0	0	4	4
6.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
PRACTICAL								
7.	MB3111	Simulation Laboratory – I	PCC	0	0	2	2	1
			TOTAL	**18**	**2**	**4**	**24**	**22**

SEMESTER - II

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	MB3201	Electric VehicleTechnology	PCC	4	0	0	4	4
2.	MR3152	Sensors and Data Acquisition System	PCC	3	0	4	7	5
3.	EY3061	Energy StorageTechnologies	PCC	3	0	0	3	3
4.		Professional Elective - I	PEC	3	0	0	3	3
5.		Professional Elective - II	PEC	3	0	0	3	3
6.		Professional Elective – III	PEC	3	0	0	3	3
PRACTICAL								
7.	MB3211	Simulation Laboratory – II	PCC	0	0	4	4	2
8.	MB3212	Electric Vehicle Laboratory	PCC	0	0	4	4	2
9.	MB3213	Summer Internship	EEC	0	0	0	0	2
			TOTAL	**19**	**0**	**12**	**31**	**27**

SEMESTER-III

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective IV	PEC	3	0	0	3	3
2.		Professional Elective V	PEC	3	0	0	3	3
PRACTICAL								
3.	IC3361	Research Data Analysis Laboratory	PCC	0	0	2	2	1
4.	MB3311	Technical Seminar	EEC	0	0	2	2	1
5.	MB3312	Project Work - I	EEC	0	0	12	6	6
			TOTAL	**6**	**0**	**16**	**16**	**14**

SEMESTER-IV

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICAL								
1.	MB3411	Project Work – II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL: 75 CREDITS

Attested

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FOUNDATION COURSES (FC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	MA3155	Advanced Numerical Methods	FC	4	0	0	4	4
2.	MR3151	Concepts in Electronics Engineering	FC	2	0	2	4	3

PROFESSIONAL CORE COURSES (PCC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	IC3102	Modern Engine Technologies	PCC	3	0	0	3	3
2.	EY3151	Fluid Mechanics and Heat Transfer	PCC	3	1	0	3	4
3.	MB3101	Automotive Technology	PCC	4	0	0	4	4
4.	MB3201	Electric Vehicle Technologies	PCC	4	0	0	4	4
5.	MR3152	Sensors and Data Acquisition System	PCC	3	0	0	3	3
6.	EY3061	Energy Storage Technologies	PCC	3	0	0	3	3
7.	MB3212	Electric Vehicle Laboratory	PCC	0	0	2	2	1
8.	MB3111	Simulation Laboratory- I	PCC	0	0	2	2	1
9.	MB3212	Electric Vehicle Laboratory	PCC	0	0	4	4	2
10.	IC3361	Research Data Analysis Laboratory	PCC	0	0	2	2	1

Attested

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PROFESSIONAL ELECTIVE COURSES (PEC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	EY3052	Fuel Cell Technology	PEC	3	0	0	3	3
2.	RA3053	Thermal Management of Electronics and Batteries	PEC	3	0	0	3	3
3.	ET3251	Automotive Embedded Systems	PEC	3	0	0	3	3
4.	IC3054	Autonomous and Connected Vehicle Systems	PEC	3	0	0	3	3
5.	IC3052	Hydrogen – Production and Utilisation	PEC	3	0	0	3	3
6.	IC3051	Advanced Combustion Technologies	PEC	3	0	0	3	3
7.	IC3253	Computational Fluid Dynamics for Mobility Systems	PEC	2	0	2	4	3
8.	MB3001	Optimization Techniques for Mobility	PEC	3	0	0	3	3
9.	MB3002	Machine Learning in Mobility	PEC	3	0	0	3	3
10.	PW3151	Electric Vehicle Charging Infrastructure	PEC	3	0	0	3	3
11.	PW3052	Electric Vehicles and Power Management	PEC	3	0	0	3	3
12.	PW3059	Electrical Drives and Control	PEC	3	0	0	3	3
13.	ET3252	Embedded Control for Electric Drives	PEC	2	0	2	4	3

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	MB3311	Technical Seminar	EEC	0	0	2	2	1
2.	MB3213	Summer Internship – 4 weeks	EEC	0	0	0	0	2
3.	MB3312	Project Work – I	EEC	0	0	6	6	6
4.	MB3411	Project Work – II	EEC	0	0	24	24	12

S.NO	ME MOBILITY ENGINEERING					
	Subject Area	Credits Per Semester				Credits Total
		I	II	III	IV	
1.	FC	7	0	0	0	7
2.	PCC	12	16	1	0	29
3.	PEC	0	9	6	0	15
4.	RMC	3	0	0	0	3
5.	EEC	0	2	7	12	21
	TOTAL CREDIT	**22**	**27**	**14**	**12**	**75**

MA3155 ADVANCED NUMERICAL METHODS **L T P C**
4 0 0 4

OBJECTIVES:

- To impart knowledge in understanding the advantages of various solution procedures of solving the system of linear and nonlinear equations.
- To give a clear picture about the solution methods for solving the BVPs and the system of IVPs.
- To acquire knowledge in solving time dependent one and two dimensional parabolic PDEs by using various methodologies.
- To strengthen the knowledge of finite difference methods for solving elliptic equations.
- To get exposed to the ideas of solving PDEs by finite element method.

UNIT I ALGEBRAIC EQUATIONS 12

Systems of linear equations: Gauss Elimination method, pivoting techniques, Thomas algorithm for tridiagonal system – Jacobi, Gauss Seidel, SOR iteration methods - Systems of nonlinear equations: Fixed point iterations, Newton Method, Eigenvalue problems: power method, Faddeev – Leverrier Method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS 12

Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, solution of stiff ODEs, shooting method, BVP: Finite difference method, collocation method, orthogonal collocation method, Galerkin finite element method.

UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATION 12

Parabolic equations: explicit and implicit finite difference methods, weighted average approximation - Dirichlet and Neumann conditions – Two dimensional parabolic equations – ADI method; First order hyperbolic equations – method of characteristics, Lax - Wendroff explicit and implicit methods; numerical stability analysis, method of lines – Wave equation: Explicit scheme-Stability of above schemes.

UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS 12

Laplace and Poisson's equations in a rectangular region: Five point finite difference schemes, Leibmann's iterative methods, Dirichlet and Neumann conditions – Laplace equation in polar coordinates: finite difference schemes – approximation of derivatives near a curved boundary while using a square mesh.

UNIT V FINITE ELEMENT METHOD 12

Partial differential equations – Finite element method - collocation method, orthogonal collocation method, Galerkin finite element method.

TOTAL: 60 PERIODS

OUTCOMES:

At the end of the course, students will be able to

CO1 Get familiarized with the methods which are required for solving system of linear, nonlinear equations and eigenvalue problems.

CO2 Solve the BVPs and the system of IVPs by appropriate methods discussed.

CO3 Solve time dependent parabolic PDEs by using various methodologies up to dimension two.

CO4 Solve elliptic equations by finite difference methods.

CO5 Use the ideas of solving PDEs by finite element method.

REFERENCES:

1. Burden, R.L., and Faires, J.D., "Numerical Analysis – Theory and Applications", Cengage Learning, India Edition, New Delhi, 2010.
2. Gupta S.K., "Numerical Methods for Engineers", New Age Publishers, 3rd Edition, New Delhi, 2015.
3. Jain M. K., Iyengar S. R. K., Jain R.K., "Computational Methods for Partial Differential Equations", New Age Publishers, 2nd Edition, New Delhi, 2016.
4. Morton K.W. and Mayers D.F., "Numerical solution of partial differential equations", Cambridge University press, Cambridge, 2005.
5. Sastry S.S., "Introductory Methods of Numerical Analysis", Prentice - Hall of India Pvt. Limited, 5th Edition, New Delhi, 2012.
6. Saumyen Guha and Rajesh Srivastava, "Numerical methods for Engineering and Science", Oxford Higher Education, New Delhi, 2010.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	2
CO2	3	3	3	3	2	2
CO3	3	3	3	3	2	2
CO4	3	3	3	3	2	2
CO5	3	3	3	3	2	2

MR3151 CONCEPTS IN ELECTRONICS ENGINEERING

L	T	P	C
2	0	2	3

COURSE OBJECTIVES:

1. To recall the functionality of fundamental electronic components.
2. To understand the functions of operational amplifier and its applications.
3. To review and use the logic gates for various digital circuit development.
4. To understand the functions and uses in measurement.
5. To learn the power management on various electronic units.

UNIT I ELECTRONIC COMPONENTS AND DEVICES 6

Resistors, Capacitors, Inductors, Transformers – Types and Properties - PN Junction Diodes, Zener Diodes, Transistors, Thyristors – Types - Operating Mechanism -Characteristics and Applications. LED Construction and Working – Applications, Types of Displays and its Construction – Applications.

UNIT II OPERATIONAL AMPLIFIERS AND APPLICATIONS 6

Operational Amplifiers – Principles, Specifications, Characteristics and Applications - Arithmetic Operations, Integrator, Differentiator, Comparator, Schmitt Trigger, Instrumentation Amplifier, Active Filters, Linear Rectifiers, Waveform Generators, Sample and Hold Circuits, D/A Converters, Feedback and Power Amplifiers, Sine Wave Oscillators.

UNIT III DIGITAL ELECTRONICS 6

Number Systems – Logic Gates – Boolean Algebra – Simplification of Boolean Functions – Study of Combinational Logic Circuits - Full Adder, Code Converters, Multiplexers, Decoders, Study of Sequential Logic Circuits - Flip-Flops, Counters, Shift Registers – Memory - Types - Solid State Memory – A/D Converters.

UNIT IV MEASURING INSTRUMENTS 6

Regulated Power Supply - Rectifiers and Filters – Switching Power Supplies - Thermal Considerations. Measurement of Voltage, Current, Frequency and Power Using Multi Meters, Oscilloscopes, Recorders, Data Loggers, Signal Sources, Counters, Analyzers and Printers.

UNIT V POWER MANAGEMENT 6

Energy Estimation – Power Estimation and Optimization of Electrical and Electronics Elements, Integrated System - Sensors, Data Acquisition System - Drives, Switching Devices, Actuators and Controllers - Batteries - Types, Specification - Power Conversion Methods.

TOTAL 30 PERIODS

LIST OF EXPERIMENTS:

1. Study of Digital Storage oscilloscope.
2. Experimentation with CRO.
3. Design of DC power supplies
4. Design of Inverting Amplifier and Non-Inverting Amplifiers
5. Design of Instrumentation amplifier.
6. Design of analog filters.
7. Design of combinational circuits and sequential circuits.
8. Design of A/D converters and D/A converters.
9. RC Servo motor driver circuit.
10. Design of stepper motor driver circuit

30 PERIODS

COURSE OUTCOMES:
Upon completion of this course, the students will be able to:

CO1 State the fundamentals of electronic, circuits and measurement instruments.
CO2 Recognize the components, circuits and measurement instruments operation.
CO3 Design and develop the circuits using electronics components and measure using instruments.
CO4 Analyse the circuit by measuring parameters using measurement instruments.
CO5 Create circuit to perform the signal conditioning, power management and logic operations

REFERENCES:

1. Millman and Halkias, “Electronic Devices and Circuits”, McGraw Higher Ed., 2015.
2. Jacob Millman, “Microelectronics Digital and Analog Circuits and Systems”, McGraw-Hill, 2014.
3. Helfrick A.D and Cooper .W. D. “Modern Electronic Instrumentation and Measurements Techniques”, Prentice Hall, 2016.
4. Roy Choudhury, “Linear Integrated Circuits”, New Age, 2018
5. Malvino & Leach, “Digital Principles and Application”, Tata McGraw-Hill Education, 2002.

COs	POs					
	1	**2**	**3**	**4**	**5**	**6**
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	2	1	1	2	1
4	2	1	1	1	2	1
5	2	2	1	1	1	1
Avg	**1.4**	**1.4**	**1**	**1**	**1.4**	**1**

IC3102 MODERN ENGINE TECHNOLOGIES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. The objective of this course is to impart knowledge about modern fueling system, actuation and boosting technologies, modern engine technologies, and after treatment systems employed in modern engines

UNIT I MODERN FUELING SYSTEM TECHNOLOGY 9

Introduction – Background, Multi-point Fuel Injection (MPFI), Gasoline Direct Injection (GDI), CNG Direct Injection, Hydrogen Direct Injection, Common Rail Direct Injection (CRDI), Dual Fuel System – Working, Benefits of Dual Fuel Operation, Applications of Dual Fuel Engines, Importance of Dual Fuel Engines Availability.

UNIT II ACTUATION TECHNOLOGIES 9

Variable Valve Timing (VVT) – Needs, VVT Terminologies, Methods of Implementing VVT. Exhaust Gas Recirculation (EGR) System – Background, EGR – Hot and Cold EGR, Vacuum Modulated EGR Valve Actuation, Electric EGR Actuation, Cooling System for EGR, Effects of EGR on NOx and HC formation, Advantages of EGR. Intelligent Cylinder De-Activation Technologies, Cam less Engines.

UNIT III BOOSTING TECHNOLOGIES 9

Turbocharger – Need, Parts, Working. Waste Gate Turbocharger, Variable Geometry Turbocharger, Electric Turbochargers. Turbo Compounding Technologies.

UNIT IV MODERN ENGINES AND HYBRID TECHNOLOGIES 9

SA-HCCI Engines, RCCI Engines, GDCI Engines, CNG/LNG Powered Engines, Hydrogen Powered Combustion Engines, Ammonia Powered Combustion Engines. VCR and Variable Stroke Engines. Split-Cycle Engines.

Hybrids – Terminologies, Working of Hybrids. Types of Hybrids – Parallel Hybrid, Range Extender Hybrid, Plug-in Hybrids. Conventional ICE+ Battery Powered Motor Hybrids, Advanced Combustion Engines + Battery Powered Motor Hybrids, ICE+ Fuel Cell Hybrids

UNIT V MODERN AFTER TREATMENT TECHNOLOGIES 9

Three Way Catalytic Converter (TWC), Diesel Oxidation Catalysts (DoC), Diesel and Gasoline Particulate Filters, Lean-NOx or De-NOx Catalyst, Selective Catalyst Reduction Technique, Ammonia Slip Catalyst / Cleanup Catalyst, Ammonia Cracking System

TOTAL 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Understanding on modern fueling system technologies
CO2 Understanding on modern actuation technologies
CO3 Understanding on modern boosting technologies
CO4 Understanding on moder engine and hybrid technologies
CO5 Understanding on modern after treatment technologies

REFERENCES

1. Richard Van Basshuysen, Fred Schaefer. Modern Engine Technologies from A to Z, SAE, 2015.
2. Diesel Emission and Their Control – SAE 2006-12-01
3. Modern Technologies in Automobiles: https://www.researchgate.net/publication/328354823

CO- PO MAPPING

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	1
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	1.5

EY3151 FLUID MECHANICS AND HEAT TRANSFER

L	T	P	C
3	1	0	4

OBJECTIVE:

The main objective of the course is to impart knowledge to students on the concepts of fluid kinematics, boundary layer theory, incompressible and compressible fluid flow analysis. The course is also useful to enhance the student knowledge on various modes of heat transfer and the applications of heat transfer.

UNIT – I FLUID KINEMATICS AND BOUNDARY LAYER THEORY 12

Three dimensional forms of governing equations – Mass, Momentum, and their engineering applications. Rotational and irrotational flows – vorticity – stream and potential functions. Boundary Layer – displacement, momentum and energy thickness – laminar and turbulent boundary layers in flat plates and circular pipes.

UNIT – II INCOMPRESSIBLE AND COMPRESSIBLE FLOWS 12

Laminar flow between parallel plates – flow through circular pipe – friction factor – smooth and rough pipes – Moody diagram – losses during flow through pipes. Pipes in series and parallel – transmission of power through pipes.
One dimensional compressible flow analysis – flow through variable area passage – nozzles and diffusers.

UNIT – III CONDUCTION AND CONVECTION HEAT TRANSFER 12

Conduction: Governing Equation and Boundary conditions, Extended surface heat transfer, Transient conduction – Use of Heisler-Grober charts, Conduction with moving boundaries, Stefan and Neumann problem.
Energy equation - Analogy between heat and momentum transfer – Reynolds, Colburn, Prandtl turbulent flow in a tube – High speed flows – Convection with phase change – Condensation, Boiling.

UNIT – IV RADIATION HEAT TRANSFER 12

Surface radiation – View factor analysis, Gas Radiation - Radiative Transfer Equation (RTE), Radiation properties of a participating medium, Use of Hottel's Graph, Correction factor analysis - Inverse problems in radiation transfer.

UNIT – V HEAT EXCHANGER AND HEAT PIPE 12

Heat exchanger: Classification, sizing, and rating problems – Bell Delaware method - Є-NTU method – thermo-hydraulic performance of compact heat exchanger.
Heat Pipes: Classification, Thermal analysis - performance improvement techniques.

TOTAL: 60 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO 1 Identify, formulate, and analyze the governing equations for various engineering applications.
CO 2 Learn the flow concepts of incompressible and compressible flow.
CO 3 Solve the conduction and convection heat transfer problems.
CO 4 Understand the importance of radiation heat transfer in gases and inverse solution methods.
CO 5 Design a heat exchanger and heat pipe as per the industrial needs.

REFERENCES:

1. Yunus A Cengel and John M Cimbala, “Fluid Mechanics Fundamentals and Applications,” McGraw-Hill, 2018.
2. Venkateshan S P., “Heat Transfer “, Ane Books Pvt. Ltd, 2016
3. Holman J P, “Heat Transfer”, McGraw-Hill, 2010.
4. Ozisik M N., “Heat Transfer – A Basic Approach”, McGraw Hill Co, 1985.
5. Adrian Bejan, Convection Heat Transfer, Wiley, Fourth Edition, 2013
6. Bahman Zohuri, “Heat Pipe Design and Technology”, Taylor and Francis Group, LLC, 2011.

CO – PO MAPPING

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	-	-	3	1	1
2	3	-	-	3	1	1
3	3	-	2	3	2	1
4	3	-	2	3	2	1
5	3	-	2	3	2	1
Avg.	**3**	**-**	**2**	**3**	**1.6**	**1**

MB3101 AUTOMOTIVE TECHNOLOGY

	L	T	P	C
	4	0	0	4

COURSE OBJECTIVES

1. To distinguish different types of chassis, frames and body and its component design.
2. To introduce the automobile subsystems
3. To introduce the concept of aerodynamics in automobiles
4. To introduce the concept of vehicle dynamics
5. To introduce different automobile safety technologies

UNIT I CHASSIS & LAYOUT 12

Basic construction of chassis, types of chassis layout, types of Body, types of frames, loads acting on vehicle frame, power sources - internal combustion engine - fuel cell – battery.

UNIT II AUTOMOBILE POWERTRAIN 12

Clutch – principle – construction – type, transmission – principle – construction – type, torque converters, drive shaft, axle, differential, wheels and tires.

UNIT III AUXILIARY SYSTEMS 12

Braking system - types, steering geometry - steering system - types, suspension system – types, cooling and lubrication system, starting system, electrical system, HVAC.

UNIT IV ENGINE & VEHICLE TESTING 12

Engine testing - related standards – test cycles, dynamometers – transient dynamometer – chassis dynamometers, test tracks, wind tunnel testing, safety & crash testing – NCAP – Injury criteria, central motor vehicle rules – homologation, vehicle service and maintenance, on board diagnostics.

UNIT V AUTOMOBILE SAFETY TECHNOLOGIES 12

Antilock braking system, electronic brake force distribution, stability control system, traction control system, collision avoidance system, airbag, seatbelt - pretensioner, cruise control, automatic high beam, adaptive headlights, daytime running lamp, active headrests, crumple zone, lane assist, driver fatigue detection, tire pressure monitoring.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Differentiate different types of automobiles based on body features.

CO2 Identify automotive power train components

CO3 Identify auxiliary systems

CO4 Carryout engine and vehicle testing

CO5 Demonstrate understanding of automobile safety technologies

REFERENCES:

1. Robert Bosch GmbH, "Automotive Handbook", 11th Edition, 2022, Willey.
2. Joseph Heitner, "Automotive Mechanics," 2nd Edition, 2006, CBS.
3. William H. Crouse, Donald L. Anglin, "Automotive Mechanics", 10th Edition, 2017, McGraw Hill Education.
4. Heinz Heisler, "Advanced Vehicle Technology," 2nd Edition, 2002, Butterworth-Heinemann.
5. Hans B Pacejka, "Tyre and Vehicle Dynamics", 3rd edition, 2012, SAE International.
6. William B. Ribbens,"Understanding Automotive Electronics",8thedition,2017, Butterworth Heinemann.
7. Hucho, W.H., "Aerodynamics of Road vehicles", 4th Edition, SAE,1998,

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	2	-	3	1
2	3	1	2	-	3	-
3	3	1	2	-	3	-
4	3	1	1	-	3	-
5	3	2	3	-	3	2
Avg	3	2	2	-	3	1.5

RM3151 RESEARCH METHODOLOGY AND IPR **L T P C**
2 1 0 3

OBJECTIVES:

To impart knowledge on

- Formulation of research problems, design of experiment, collection of data, interpretation and presentation of result
- Intellectual property rights, patenting and licensing

UNIT I RESEARCH PROBLEM FORMULATION 9

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II RESEARCH DESIGN AND DATA COLLECTION 9

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV INTELLECTUAL PROPERTY RIGHTS 9

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V PATENTS 9

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Upon completion of the course, the student can

CO1: Describe different types of research; identify, review and define the research problem

CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data

CO3: Explain the process of data analysis; interpret and present the result in suitable form

CO4: Explain about Intellectual property rights, types and procedures

CO5: Execute patent filing and licensing

REFERENCES:

1. Cooper Donald R, Schindler Pamela S and Sharma JK, "Business Research Methods", Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, "Research methodology for natural sciences", IISc Press, Kolkata, 2022,
3. Catherine J. Holland, "Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets", Entrepreneur Press, 2007.

4. David Hunt, Long Nguyen, Matthew Rodgers, "Patent searching: tools & techniques", Wiley, 2007.
5. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, "Professional Programme Intellectual Property Rights, Law and practice", September 2013.

MB3111	SIMULATION LABORATORY - I	L	T	P	C
		0	0	2	1

COURSE OBJECTIVES

1. The objective of this course is to make the student familiarize with simulation softwares for electric vehicle applications

LIST OF EXPERIMENTS

1. Modelling of a hybrid vehicle using appropriate software
2. Performance matching for a hybrid vehicle
3. Performance studies on two / three / four wheeled electric vehicle using appropriate software
4. Simulation of Heating / Cooling requirement of battery and control system
5. Aerodynamic performance study of electric vehicle

NOTE: The above exercises are only guidelines to maintain the standard for teaching and conduct of examination.

SIMULATION LAB – REQUIREMENT:

1. Software – For preprocessing, Solving and post-processing : Open-Foam / Any commercially available CFD codes and mathematical equation solving softwares.
2. Every student in a batch must be provided with a hardware terminal
3. Hardware should compatible with the requirement of the above software

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Model and validate any electric / hybrid vehicle using suitable software
CO2 Simulate the temperature distribution of an EV power pack / control system
CO3 Carryout simulation studies on electric vehicle aerodynamics

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	2
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	2

MB3201 ELECTRIC VEHICLE TECHNOLOGY

L	T	P	C
4	0	0	4

COURSE OBJECTIVES

1. The objective of this course is to introduce the basic concepts of electric vehicle and their characteristics and their architecture, various energy storage systems, different types of motors and their characteristics and to design an electric vehicle

UNIT I NEED FOR ELECTRIC VEHICLES 12

History and need for electric and hybrid vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies, comparison of diesel, petrol, electric and hybrid vehicles, limitations, technical challenges

UNIT II ELECTRIC VEHICLE ARCHITECTURE 12

Electric vehicle types, layout and power delivery, performance – traction motor characteristics, tractive effort, transmission requirements, vehicle performance, energy consumption, Concepts of hybrid electric drive train, architecture of series and parallel hybrid electric drive train, merits and demerits, mild and full hybrids, plug-in hybrid electric vehicles and range extended hybrid electric vehicles, Fuel cell vehicles.

UNIT III ENERGY STORAGE 12

Batteries – types – lead acid batteries, nickel-based batteries, and lithium based batteries, electrochemical reactions, thermodynamic voltage, specific energy, specific power, energy efficiency, Battery modeling and equivalent circuit, battery charging and types, battery cooling, Ultra-capacitors, Flywheel technology, Hydrogen fuel cell, Thermal Management of the PEM fuel cell

UNIT IV ELECTRIC DRIVES AND CONTROL 12

Types of electric motors – working principle of AC and DC motors, advantages and limitations, DC motor drives and control, Induction motor drives and control, PMSM and brushless DC motor -drives and control , AC and Switch reluctance motor drives and control – Drive system efficiency – Inverters – DC and AC motor speed controllers

UNIT V DESIGN OF HYBRID ELECTRIC VEHICLES 12

Materials and types of production, Chassis skate board design, motor sizing, power pack sizing, component matching, Ideal gear box – Gear ratio, torque–speed characteristics, Dynamic equation of vehicle motion, Maximum tractive effort – Power train tractive effort Acceleration performance, rated vehicle velocity – maximum gradability, Brake performance, Electronic control system, safety and challenges in electric vehicles. Case study of NISSAN LEAF, TOYOTA PRIUS, TESLA model 3, and RENAULT ZOE cars

TOTAL: 60 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

- **CO1** Understand the advantages and challenges of electric vehicles
- **CO2** Understand and select appropriate electric vehicle architecture
- **CO3** Adopt a suitable energy storage system for a vehicle
- **CO4** Choose an appropriate electric motor and drive system for a vehicle
- **CO5** Design a suitable electric vehicle for various applications

REFERENCES:

1. John G Hayes and G Abaas Goodarzi, Electric Powertrain -, 1st Edition, John Wiley & Sons Ltd., 2018.
2. Iqbal Husain, “Electric and Hybrid Vehicles – Design Fundamentals”, Second Edition, CRC Press,2019
3. Alfred Rufer, “Energy Storage systems and components”, CRC Press,2017
4. Hong Cheng, ―Autonomous Intelligent Vehicles: Theory, Algorithms & Implementation‖, Springer, 2011
5. Berker B., James W. J. & A. Emadi, “Switched Reluctance Motor Drives”, CRC Press 2017
6. Ehsani, Mehrdad, et al. Modern electric, hybrid electric, and fuel cell vehicles. CRC press, 2017.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	1
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	1.5

MR3152 SENSORS AND DATA ACQUISITION SYSTEM

L	T	P	C
3	0	4	5

COURSE OBJECTIVES:

1. To learn the various types of sensors, transducers, sensor output signal types, calibration techniques, formulation of system equation and its characteristics.
2. To understand basic working principle, construction, Application and characteristics of displacement, speed and ranging sensors.
3. To understand and analyze the working principle, construction, application and characteristics of force, magnetic and heading sensors.
4. To learn and analyze the working principle, construction, application and characteristics of optical, pressure, temperature and other sensors.
5. To familiarize students with different signal conditioning circuits design and data acquisition system.

UNIT I SENSOR CLASSIFICATION, CHARACTERISTICS AND SIGNAL TYPES 9

Basics of Measurement – Classification of Errors – Error Analysis – Static and Dynamic Characteristics of Transducers – Performance Measures of Sensors – Classification of Sensors – Sensor Calibration Techniques – Sensor Outputs - Signal Types - Analog and Digital Signals, PWM and PPM.

UNIT II DISPLACEMENT, PROXIMITY AND RANGING SENSORS 9
FORCE, MAGNETIC AND HEADING SENSORS

Displacement Sensors – Brush Encoders - Potentiometers, Resolver, Encoders – Optical, Magnetic, Inductive, Capacitive, LVDT – RVDT – Synchro – Microsyn, Accelerometer – Range Sensors - Ultrasonic Ranging - Reflective Beacons - Laser Range Sensor (LIDAR) – GPS - RF Beacons

UNIT III FORCE, MAGNETIC AND HEADING SENSORS 9

Strain Gage – Types, Working, Advantage, Limitation, and Applications: Load Measurement – Force and Torque Measurement - Magnetic Sensors – Types, Principle, Advantage, Limitation, and Applications - Magneto Resistive – Hall Effect, Eddy Current Sensor - Heading Sensors – Compass, Gyroscope and Inclinometers

UNIT IV OPTICAL, PRESSURE, TEMPERATURE AND OTHER SENSORS 9

Photo Conductive Cell, Photo Voltaic, Photo Resistive, LDR – Fiber Optic Sensors – Pressure – Diaphragm – Bellows - Piezoelectric - Piezo-resistive - Acoustic, Temperature – IC, Thermistor, RTD, Thermocouple – Non-Contact Sensor - Chemical Sensors - MEMS Sensors - Smart Sensors.

UNIT V DATA ACQUISITION SYSTEM 9

Need for Signal Conditioning – Resistive, Inductive and Capacitive Bridges for Measurement - DC and AC Signal Conditioning – Analog and Digital Data Acquisition Systems-ADC-DAC-Data Sampling-Parameters Measured using DAQ- DAQ Cards and Modules- DAQ Software.

45 PERIODS

LIST OF EXPERIMENTS:

1. Experiments Using Strain Gauge Sensor: Load Measurement, Torque
2. Determine the characteristics of Pressure Sensor.
3. Displacement Measurement using Inductive type-LVDT and Magnetic type - Hall Effect Sensor.
4. Determine the Characteristics of Various Temperature Sensors.
5. Determine the Characteristics of Various Light Detectors (Optical Sensors).
6. Distance Measurement using Ultrasonic and Laser Sensor.
7. Determine angular velocity using gyroscope.
8. Experiment on accelerometer to determine amplitude and frequency of Vibration.
9. Speed and Position Measurement Using Encoders.
10. Experiment on acquisition of analog signal using DAQ.
11. Experiment on acquisition of digital signal using DAQ.
12. Design and realize circuit to convert change in resistance, inductance and capacitance to voltage.

60 PERIODS
TOTAL 105 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 State the principles of various sensor, sensor characteristics, signal types, calibration methods.
CO2 Determine the transfer function and empirical relation of sensors through sensor response study
CO3 Describe the operation of sensors, circuits and data acquisition system
CO4 Analyze and select the suitable sensor for the given applications.
CO5 Select and design suitable signal conditioning circuit for data acquisition.

REFERENCES

1. Ernest O. Doeblin, “Measurement system, Application and Design”, Tata McGraw Hill Publishing Company Ltd., 2004.
2. Jacob Fraden, “Handbook of Modern Sensors, Physics, Design and Applications”, Springer, 2016.
3. John P. Bentley., “Principle of Measurement systems”, Pearson Prentice Hall, 2008.
4. Patranabis D., “Sensor and Actuators”, Prentice Hall of India (Pvt) Ltd., 2005.
5. Renganathan S., “Transducer Engineering”, Allied Publishers (P) Ltd., 2003

COs	POs					
	1	2	3	4	5	6
1	1	1	-	1	-	1
2	1	1	1	2	1	1
3	1	1	1	1	1	1
4	2	2	2	1	2	1
5	2	1	2	2	1	1
Avg	**1.4**	**1.2**	**1.2**	**1.4**	**1**	**1**

EY3061	ENERGY STORAGE TECHNOLOGIES	L	T	P	C
		3	0	0	3

OBJECTIVE:
To understand the significance and need for various types of energy storage technologies and their uses for real world applications. This course will also enable students to understand the Green Energy Storage of Hydrogen and the challenges associated

UNIT – I INTRODUCTION TO ENERGY STORAGE 9

Necessity of Energy Storage – Types of Energy Storage – Thermal, Mechanical, Chemical, Electrochemical and Electrical - Comparison of Energy Storage Technologies.

UNIT – II THERMAL ENERGY STORAGE SYSTEM 9

Thermal Energy Storage – Types – Sensible, Latent and Thermo-chemical – Sensible Heat Storage - Simple water and rock bed storage system – pressurized water storage system – Stratified System - Latent Heat Storage System - Phase Change Materials – Simple units, packed bed storage units - Other Modern Approaches.

UNIT – III ELECTRICAL ENERGY STORAGE 9

Batteries - Fundamentals and their Working – Battery performance, Charging and Discharging - Storage Density - Energy Density - Battery Capacity - Specific Energy - Memory Effect - Cycle Life - SOC, DOD, SOL - Internal Resistance - Coulombic Efficiency and Safety issues. Battery Types - Primary and Secondary – Lead Acid, Nickel – Cadmium, Zinc Manganese dioxide, Zinc-Air, Nickel hydride, Lithium Ion.

UNIT – IV HYDROGEN ENERGY STORAGE 9

Hydrogen Storage Options – Physical and Chemical Methods - Compressed Hydrogen – Liquefied Hydrogen – Metal Hydrides, Chemical Storage - Other Novel Methods - comparison - Safety and Management of Hydrogen - Applications - Fuel Cells.

UNIT – V ALTERNATE ENERGY STORAGE TECHNOLOGIES 9

Flywheel, Super Capacitors - Pumped Hydro Energy Storage System - Compressed Air Energy Storage System, SMES - Concept of Hybrid Storage – Principles, Methods, and Applications - Electric and Hybrid Electric Vehicles.

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Identify the energy storage technologies for suitable applications.
CO2 Apply the appropriate thermal energy storage methods suitably.
CO3 Introduce the concepts, types and working of various batteries.
CO4 Understand the use of Hydrogen as Green Energy for our Future.
CO5 Recognize and choose appropriate methods of Energy Storage and Hybrid Systems.

REFERENCES:

1. Ibrahim Dincer and Mark A. Rosen, "Thermal Energy Storage Systems and Applications", John Wiley & Sons 2002.
2. James Larminie and Andrew Dicks, "Fuel cell systems Explained", Wiley publications, 2003.
3. Luisa F. Cabeza, "Advances in Thermal Energy Storage Systems: Methods and Applications", Elsevier Woodhead Publishing, 2015.

4. Robert Huggins, “Energy Storage: Fundamentals, Materials and Applications”, 2nd edition, Springer, 2015.
5. Ru-shiliu, Leizhang, Xueliang sun, “Electrochemical technologies for energy storage and conversion”, Wiley publications, 2012.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	2	3	-	-	3	2
2	2	3	-	-	3	2
3	2	3	-	-	3	3
4	2	3	-	-	3	3
5	2	3	-	-	3	3
Avg	**2**	**2**	**-**	**-**	**3**	**2.6**

Attested

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MB3211 **SIMULATION LABORATORY - II** **L T P C**
0 0 4 2

COURSE OBJECTIVES

1. The objective of this course is to make the student familiarize with simulation softwares for electric vehicle applications

LIST OF EXPERIMENTS

1. Modelling of a hybrid vehicle using appropriate software
2. Performance matching for a hybrid vehicle
3. Simulation of Heating / Cooling requirement of battery and control system
4. Aerodynamic performance study of electric vehicle
2. Engine intake flow analysis using different port shapes
3. Engine exhaust flow analysis
4. Engine in-cylinder cold flow analysis for the given engine sector model
5. Fuel spray studies
6. Combustion analysis – arriving at p- theta and heat release rate

NOTE: The above exercises are only guidelines to maintain the standard for teaching and conduct of examination

SIMULATION LAB – REQUIREMENT:

1. Software – For preprocessing – Any 3D Modelling software compatible for the geometry, along with meshing software(s) capable of meshing different type of geometry
2. Solving and post-processing Open-FOAM / Any commercially available CFD codes and mathematical equation solving softwares.

Every student in a batch must be provided with a hardware terminal with atleast 16 GB RAM , SSD HDD 512 GB capacity, and with dedicated Graphics card of atleast 4 GB

COURSE OUTCOMES:
On successful completion of this course the student will be able to
CO1 Model and validate any electric / hybrid vehicle using suitable software
CO2 Simulate the temperature distribution of an EV power pack / control system
CO3 Carryout simulation studies on electric vehicle aerodynamics

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	2
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	2

MB3212 **ELECTRIC VEHICLE LABORATORY**

L	T	P	C
0	0	4	2

COURSE OBJECTIVES

1. The objective of this course is make the student learn the testing procedure of electric vehicles with different types of charging system, and use appropriate charger to ensure longer battery life

LIST OF EXPERIMENTS:

1. Study of Grid to Vehicle (G2V) charging and Vehicle to Grid (V2G) charging.
2. Study of various EV testing equipments – EVSE, Emulator etc.,
3. Performance Analysis of slow and fast EV chargers.
4. Performance Testing of an Electric Vehicle.
5. Performance Analysis of various Battery Technologies.
6. Implementation of Smart Battery Management System (SBMS).
7. Characterization of Power and Efficiency for e-bicycle

TOTAL: 60 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Solve dynamic equations involved in power electronics.
CO2 Acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering
CO3 Model and analyze different rectifier circuits using computational software and to understand their various operating modes.
CO4 Analyze various power quality issues due to increasing EV charging infrastructure
CO5 Formulate, design, simulate power supplies for generic load and for machine loads

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	2
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	2

MB3213 **SUMMER INTERNSHIP**

L	T	P	C
0	0	0	2

COURSE OBJECTIVES

1. To provide industrial exposure, understand work pattern and feel a hands-on experience of working in an industry.

   The Summer Internship has to be carried out in core industries during the 2nd semester vacation.
   - Minimum period of training = 4 weeks.
   - Evaluation to be carried out on the first week of 3rd semester

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Experience working culture in industry.
CO2 Understand nuances of power unit testing, validation and instrumentation
CO3 Carry out dissertation work and solve drive / power pack specific problems using the exposure gained in the internship.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	2	3
2	3	3	3	3	2	3
3	3	3	3	3	2	3
Avg	3	3	3	3	2	3

IC3361 RESEARCH DATA ANALYSIS LABORATORY

L	T	P	C
0	0	2	1

COURSE OBJECTIVES

1. The objective of the course is to acquire knowledge on the various aspects of data presentation, data collection, documentation and interpretation of research data

LIST OF EXPERIMENTS

1. Interpretation and analysis of diesel engine performance data using any analytical tool
2. Plot and analysis of given engine combustion data using graphical tool
3. Uncertainty analysis of given engine emission data using graphical tool
4. Visualize the velocity, temperature, HRR using the 3D post processing file using Tec plot software
5. Optimization of biodiesel production parameters using RSM technique for given data
6. Optimization of bioethanol production parameters using RSM technique for given data
7. Prediction of pyrolysis oil yield with experimental data by using ANN technique
8. Prediction of biofuel yield with experimental data by using Genetic Algorithm
9. Optimization and prediction of engine performance, and emission characteristics using ANN and RSM technique

TOTAL: 30 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Use different plotting tools such as MS Excel and Origin for data visualization and analysis

CO2 Familiar in uncertainty analysis of experimental data in Matlab/Minitab

CO3 Post process the experimental data for 3D visualization using Tecplot software

CO4 Develop non-parametric model for prediction of unknown data using experimental data with techniques such as RSM, ANN and GA

CO5 Optimize the experimental parameters using different techniques such as RSM and GA

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	2	-	3	1
2	3	1	2	-	3	-
3	3	1	2	-	3	-
4	3	1	1	-	3	-
5	3	2	3	-	3	2
Avg	3	2	2	-	3	1.5

MB3311 **TECHNICAL SEMINAR**

L	T	P	C
0	0	2	1

COURSE OBJECTIVES

1. This course will prepare you to produce instructive, informational, and persuasive documents based on well-defined and achievable outcomes
2. This course will teach processes for analyzing writing contexts and producing effective, clean, and reader-centered documents in an efficient manner

UNIT I FUNDAMENTALS OF TECHNICAL WRITING 6

Technical Writing Fundamentals - What is technical writing? - Sentence level editing - What is a memo? Writing a Technical Description - What is a technical description? - What purpose do they serve? - Who are they serving

UNIT II REVIEW ARTICLE WRITING 6

Selection of topics, Abstract writing for review articles, literature collection and critical review of articles, Writing conclusion and future research directions, Case studies on published review articles

UNIT III RESEARCH ARTICLE WRITING 6

Selection of problem, Experimental design of the article, Checking the scientific originality and novelty of the designed experiment, Abstract writing for research articles, literature collection and critical review of previously published research articles, Presentation of results, Writing conclusion and future research directions, Case studies on published research articles.

UNIT IV FUNDAMENTALS OF POWER POINT PRESENTATION 6

Selection of template, Background, Planning of number of slides, Planning of content structure, Selection of font, font size, and color, Readability of the presentation, Animation, clarity on pictures, and videos

UNIT V REVIEW AND RESEARCH ARTICLE FORMATS 6

Journal selection, Guide to authors, publication ethics

TOTAL: 30 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Demonstrate theoretical knowledge to create effective technical writing documents
CO2 Apply and adapt flexible writing process strategies to produce clear, high-quality deliverables in a multitude of technical writing genres.
CO3 Use professional technical writing conventions of clean and clear design, style, and layout of written materials.
CO4 Gather and apply researched information that is appropriate to your field, as demonstrated by reading and analyzing documents, and citing sources correctly.
CO5 Write clearly, correctly, and concisely.

CO – PO MAPPING:

COs	POs			PSOs		
	1	2	3	1	2	3
1	1	3	1	1	2	2
2	1	3	1	1	2	2
3	1	3	1	1	2	2
Avg	1	3	1	1	2	2

MB3312	PROJECT WORK – I	L	T	P	C
		0	0	12	6

COURSE OBJECTIVES

1. The main learning objective of this course is to prepare the students for identifying a specific problem for the current need of the society and or industry, through detailed review of relevant literature, developing an efficient methodology to solve the identified specific problem.

   Note: A project topic must be selected by the students in consultation with their guides. The progress of the project is evaluated based on a minimum of three reviews. The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The project work is evaluated jointly by external and internal examiners constituted by the Head of the Department based on oral presentation and the project report.

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Identify a suitable industrial problem with regard to Mobility engineering.
CO2 Develop the required setup for testing

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
Avg	3	3	3	3	3	3

MB3411 **PROJECT WORK – II**

L	T	P	C
0	0	24	12

COURSE OBJECTIVES

1. The main learning objective of this course is to prepare the students for solving the specific problem for the current need of the society and or industry, through the formulated efficient methodology, and to develop necessary skills to critically analyse and discuss in detail regarding the project results and making relevant conclusions.

   Note: A project topic must be selected by the students in consultation with their guides. The progress of the project is evaluated based on a minimum of three reviews. The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The project work is evaluated jointly by external and internal examiners constituted by the Head of the Department based on oral presentation and the project report.

COURSE OUTCOMES:
On successful completion of this course the student will be able to

CO1 Conduct the experiments, interpret and analyse the data
CO2 Validate, present and publish the findings

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	3	3
2	3	3	3	3	3	3
Avg	3	3	3	3	3	3

Attested

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EY3052 FUEL CELL TECHNOLOGY

L	T	P	C
3	0	0	3

OBJECTIVE:

The major objective of this course is to enhance the knowledge of the students about classifications, construction, working, analysis and applications of fuel cells. This course will also enable students to understand various production and storage techniques of Hydrogen.

UNIT – I OVERVIEW 9

Basics of Fuel Cell Technology - History of Fuel Cells - Fundamentals - Components - Working Principle - Advantages and Limitations - Comparison of Fuel Cell and Battery.

UNIT – II CLASSIFICATION 9

Classification of Fuel Cells - Based on Temperature and Electrolyte - Description and working principles of various types of fuel cells - Components used - Fabrication - Applications - Merits and Demerits of PEMFC, DMFC, PAFC, AMFC, SOFC, MCFC and MFC - Recent Developments and Achievements.

UNIT – III THERMODYNAMIC AND KINETIC ASPECTS OF FUEL CELL 9

Theory - Thermodynamics - Electrochemistry - Energy Conversion Efficiency - Factors that influence Fuel Cell Efficiency - Reaction Kinetics - Electrode Kinetics - Characterization methods - Polarization and Power Density Curves - Fuel Cell Losses - Methods to improve Fuel Cell Performance.

UNIT – IV HYDROGEN PRODUCTION, STORAGE AND SAFETY 9

Hydrogen Salient Characteristics - Physical and Chemical Properties - Hydrogen Economy - Hydrogen Production Methods - Steam Reforming, Electrolysis, Coal Gasification, Biomass Conversion - Biological Methods - Photo dissociation and Photo catalytic Methods - Thermal Methods - Hydrogen Storage - Physical and Chemical Methods - Hydrogen Safety and Risk - Challenges and Management – Codes and Standards.

UNIT – V APPLICATIONS AND CHALLENGES OF FUEL CELL 9

Fuel Cell Applications - Domestic - Industrial - Commercial - Transportation and Stationary Applications - Economics and Environment Analysis - Cost and Safety - Life Cycle Analysis - Future Trends.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Get introduced to the concepts of fuel cell technology.
CO2 Recognize the need for development of various types of fuel cells and their scopes.
CO3 Understand and apply the principles of thermodynamics and reaction kinetics of fuel cell to increase the fuel cell efficiency.
CO4 Gain knowledge on the use of hydrogen as a source of green energy and understand the challenges associated.
CO5 Analyse the cost effectiveness and eco-friendliness of fuel cell technology and understand the impact on the application aspects.

REFERENCES:

1. Aulice Scibioh M. and Viswanathan B, “Fuel Cells – principles and applications’, University Press (India), 2006.
2. Ryan O. H., Suk Won C. and Whiteny C., “Fuel Cell Fundamentals”, John Wiley & Sons, 2016.
3. O’Hayre, R., Cha S. W., Colella W. and Prinz, B., “Fuel Cell Fundamentals”, John Wiley and Sons, 2005.
4. Robert Huggins, Energy Storage: Fundamentals, Materials and Applications, 2nd edition, Springer, 2015
5. Ru-shiliu, Leizhang, Xueliang sun, Electrochemical technologies for energy storage and conversion, Wiley publications, 2012.
6. Barbir F “PEM fuel cells: theory and practice” Elsevier, Burlington, MA 2005.
7. Christopher M A Brett, “Electrochemistry – Principles, Methods and Applications”, Oxford University, 2004.
8. Basu, S., “Fuel Cell Science and Technology”, Springer, 2007.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	2	3	-	-	3	1
2	2	3	-	-	3	1
3	2	3	-	-	3	1
4	2	3	-	-	3	1
5	2	3	-	-	3	1
Avg	**2**	**3**	**-**	**-**	**3**	**1**

RA3053	THERMAL MANAGEMENT OF ELECTRONICS AND BATTERIES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- To impart the knowledge on thermal management of electronic devices and batteries.
- To provide students with an appreciation for the application of heat transfer to problems in industries related to thermal management of electronics and batteries.

UNIT – I FUNDAMENTALS 9

Heat transfer modes, electronics packaging, Properties of materials used in electronics and equipment, contact and spreading resistances, heat sink design, Thermal Interface Materials & Heat Spreaders, Jedec Standards.

UNIT – II COOLING TECHNOLOGIES 9

Microchannels, Fluid selection, Jet impingement, Immersion cooling, Heat pipes, Vapour chambers, Thermoelectric coolers, MEMS / NEMS based cooling system. Current trends in cooling.

UNIT – III APPLICATIONS 9

Automobiles, Trains, Ships, Avionics, Data Centres, Laptop / Computers / Mobile phone, Internet of Things, Television, RADAR, Satellite Electronics, LED – Lights and Display units, LASER.

UNIT – IV BATTERIES 9

Types and comparison, Thermodynamics of Batteries – Energy Balance, Electrochemical Modelling – Surface, concentration, ohmic over potential and overall cell potential, Duty cycle, Performance of a battery cell, Thermal Behaviour of Batteries - Aging, Thermal runaway, heat generation rate, thermal behaviour model and impact.

UNIT – V BATTERY THERMAL MANAGEMENT SYSTEM 9

Mechanical and Thermal design of battery pack, Thermal management system – Air based, Liquid based and Phase Change Material based systems, Recent developments.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Understand the heat transfer mechanisms, need for thermal management and sources of heat generation in electronics.
2. Compare and analyse the performance of various cooling technologies.
3. Select the appropriate cooling system for specific applications.
4. Categorise the major components of batteries and elucidate the battery characteristics.
5. Identify the challenges and requirements for thermal management of batteries.

REFERENCES:

1. Younes Shabany, Heat Transfer: Thermal Management of Electronics, CRC Press Inc, 2010.
2. L.T. Yeh, Thermal Management of Microelectronic Equipment, ASME, 2016.
3. Arman Vassighi, Manoj Sachdev, Thermal and power management of integrated circuits, Springer, 2006.
4. Marc A Rosen, Aida Farsi, Battery Technology: From Fundamentals to Thermal Behaviour and Management, Elsevier, 2023.
5. Shriram Santhanagopalan, Kandler Smith, Gi-Heon Kim, Jeremy Neubauer, Ahmad A. Pesaran, Matthew Keyers, Design and Analysis of Large Lithium-Ion Battery Systems, Artech House Publishers, 2014.
6. Jerry E. Sergent, Al Krum, Thermal Management Handbook: For Electronic Assemblies, McGraw-Hill, 1998.
7. Shichun Yang, Xinhua Liu, Shen Li, Cheng Zhang, Advanced Battery Management System for Electric Vehicles, Springer, 2022.

Mapping of CO with PO

CO	PO					
	1	2	3	4	5	6
1	1	-	1	2	-	1
2	2	-	1	2	-	1
3	1	-	1	2	-	1
4	-	-	1	1	-	2
5	1	-	1	1	-	2
Avg.	1.25	-	1	1.6	-	1.4

ET3251 AUTOMOTIVE EMBEDDED SYSTEMS LT P C

3 0 0 3

UNIT I ELECTRONIC ENGINE CONTROL SYSTEMS 9

Overview of Automotive systems, fuel economy, air-fuel ratio, emission limits and vehicle performance; Automotive microcontrollers - Electronic control Unit - Hardware & software selection and requirements for Automotive applications – open source ECU - RTOS - Concept for Engine management-Standards; Introduction to AUTOSAR and Introduction to Society SAE - Functional safety ISO 26262 - Simulation and modeling of automotive system components.

UNIT II SENSORS AND ACTUATORS FOR AUTOMOTIVES 9

Review of sensors- sensors interface to the ECU, conventional sensors and actuators, Modern sensor and actuators - LIDAR sensor- smart sensors- MEMS/NEMS sensors and actuators for automotive applications.

UNIT III VEHICLE MANAGEMENT SYSTEMS 9

Electronic Engine Control - engine mapping, air/fuel ratio spark timing control strategy, fuel control, electronic ignition - Adaptive cruise control - speed control - anti-locking braking system - electronic suspension - electronic steering, Automatic wiper control - body control system; Vehicle system schematic for interfacing with EMS, ECU. Energy Management system for electric vehicles - Battery management system, power management system-electrically assisted power steering system - Adaptive lighting system - Safety and Collision Avoidance.

UNIT IV ONBOARD DIAGONSTICS AND TELEMATICS 9

On board diagnosis of vehicles - System diagnostic standards and regulation requirements Vehicle communication protocols Bluetooth, CAN, LIN, FLEXRAY, MOST, KWP2000 and recent trends in vehicle communications - Navigation - Connected Cars technology - Tracking - Security for data communication - dashboard display and Virtual Instrumentation, multimedia electronics - Role of IOT in Automotive systems

UNIT V ELECTRIC VEHICLES 9

Electric vehicles – Components - Plug in Electrical vehicle - V2G - Charging station – Aggregators - Fuel cells/Solar powered vehicles - Autonomous vehicles.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of this course, the students will have the ability in

CO1: Insight into the significance of the role of embedded system for automotive applications.

CO2: Illustrate the need, selection of sensors and actuators and interfacing with ECU

CO3: Develop the Embedded concepts for vehicle management and control systems.

CO4: Demonstrate the need of Electrical vehicle and able to apply the embedded system technology for various aspects of EVs

CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design and its application in automotive systems.

REFERENCES:

1. William B. Ribbens, “Understanding Automotive Electronics”, Elseiver,2012
2. Ali Emedi, Mehrdedehsani, John M Miller, “Vehicular Electric power system- land, Sea, Air and Space Vehicles” Marcel Decker, 2004.
3. L.Vlacic, M.Parent, F.Harahima,” Intelligent Vehicle Technologies”, SAE International,2001.
4. Jack Erjavec,JeffArias, “Alternate Fuel Technology-Electric, Hybrid& Fuel Cell Vehicles”, Cengage , 2012.
5. Electronic Engine Control technology - Ronald K Jurgen Chilton’s guide to Fuel Injection - Ford.
6. Automotive Electricals/Electronics System and Components, Tom Denton, 3rd. Edition, 2004.
7. Uwe Kiencke, Lars Nielsen, “Automotive Control Systems: For Engine, Driveline, and Vehicle”, Springer; 1 edition, March 30, 2000.
8. Automotive Electricals Electronics System and Components, Robert Bosch Gmbh, 4th Edition, 2004.
9. Automotive Hand Book, Robert Bosch, Bently Publishers, 1997.
10. Jurgen, R., Automotive Electronics Hand Book.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	2	1	1	-	2
CO2	2	3	2	2	2	3
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2
Average	**2.75**	**2.8**	**2.4**	**2.4**	**2.75**	**2.2**

IC3054 AUTONOMOUS AND CONNECTED VEHICLE SYSTEMS

	L	T	P	C
	3	0	0	3

COURSE OBJECTIVE

1. The objective of the course is to impart knowledge on the various machine learning aspects of IC engines

UNIT I INTRODUCTION TO AUTOMOUS VEHICLE TECHNOLOGY 9

Introduction- SAE autonomous level classification-Examples-Application of Autonomous vehicle, Advantages and disadvantages of autonomous vehicles

UNIT II PATH PLANNING AND DECISION MAKING 9

Principles of decision making and path planning for autonomous vehicles-Decision making approaches-Approximation-Heuristic-Graph based-Point guidance. Verification and validation of decision making and path planning-Application examples of task allocation and path planning algorithm

UNIT III SENSORS, PERCEPTION AND VISUALIZATION 9

Introduction to sensors, perception and visualization for autonomous vehicles-Sensor integration architectures and multiple sensor fusion- AI algorithm for sensor and imaging-neural networks.

UNIT IV NETWORKING AND CONNECTING VEHICLES 9

Current and future vehicle networking technologies-CAN, LIN,MOST and Flex-ray. The use of modern validation and verification methods-software-in the-loop, and hardware-in-the-loop technologies. The role of functional safety and ISO 26262 within the overall control system. Interdependency between software engineering and control system-advanced test methods for validation of safety-critical systems. Connected vehicle control (CACC). Vehicle to vehicle (v2v), vehicle to infrastructure and vehicle to cloud (v2c). Applications such as intelligent traffic signals, collaborative adaptive cruise and vehicle platooning.

UNIT V HUMAN FACTORS AND ETHICAL DECISION MAKING 9

Introduction to human factors-Human performance: perception and attention-situation awareness and error-human reliability: driver workloads and fatigue-emotion and motivation in design-Trust in autonomous vehicles and assistive technology-designing ADAS systems-Driverless vehicles and ethical dilemmas: Human factors and decision making software-Application of human factors in autonomous vehicles. International and national regulatory frameworks for CAV and their safe operation

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Gain fundamental knowledge on electric motors Estimate vehicle state based on available data.

CO2 facilitate various computer vision features and techniques

CO3 Develop motion plan for the vehicle based on the environment, behavior and interaction of objects

CO4 Describe the applications of AL in autonomous and connected vehicles.
.

CO5 Incorporate the human related factors in decision making of ADAS

REFERENCES:

1. Autonomous Driving: How the Driverless Revolution will Change the World, by Andreas Herrmann, Walter Brenner, Rupert Stadler, ISBN-10 1787148343, ISBN-13 978-1787148345, Emerald Publishing Limited, 26 March 2018.
2. Autonomous Vehicles: Technologies, Regulations, and Societal Impacts, George Dimitrakopoulos, Aggelos Tsakanikas, Elias Panagiotopoulos, Paperback ISBN: 9780323901376, eBook ISBN: 9780323901383, 1st Edition – April 14, 2021, Elsevier.
3. Driverless: Intelligent Cars and the Road Ahead (MIT Press) 1St Edition, by Hod Lipson , Melba Kurmanr), ISBN-13: 978-0262035224, ISBN-10: 0262035227, September 23, 2016.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	2	1	3	2
2	3	1	2	1	3	-
3	3	1	2	1	3	-
4	3	1	1	1	3	-
5	3	2	3	1	3	2
Avg	3	2	2	1	3	2

IC3052 HYDROGEN –PRODUCTION AND UTILIZATION

	L	T	P	C
	3	0	0	3

COURSE OBJECTIVES

1. To impart knowledge about hydrogen production from different sources
2. To impart knowledge about utilization of hydrogen in fuel cells.
3. To impart knowledge about utilization of hydrogen in IC engines.

UNIT I INTRODUCTION 9

Properties of hydrogen, safety and storage aspects of hydrogen, hydrogen leakage detection, regulation - codes – standards.

UNIT II HYDROGEN PRODUCTION FROM FOSSIL FUELS AND BIOMASS 9

Gasification, Pyrolysis, reforming - steam reforming - partial oxidation – autothermal reforming.

UNIT III HYDROGEN PRODUCTION FROM WATER 9

Fundamentals of electrolysis of water, Types of electrolyzers, sizing of electrolyzers, electrolysis parameters – current density, pressure, operating temperature, hydrogen purity

UNIT IV UTILIZATION OF HYDROGEN IN FUEL CELL 9

Introduction to fuel cells, thermodynamics and electrochemical kinetics of fuel cells, Fuels cells for automotive applications – Sizing - Performance evaluation - Parameters affecting the efficiency

UNIT V UTILIZATION OF HYDROGEN IN IC ENGINES 9

Merits and demerits of hydrogen as a fuel for IC engines, Strategies for using hydrogen as fuel in IC engines, hydrogen fuel supply system, Performance – combustion - emission characteristics

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Demonstrate understanding of properties of hydrogen

CO2 Demonstrate understanding of technologies to produce hydrogen from fossil fuel and biomass.

CO3 Demonstrate understanding of technologies to produce hydrogen by electrolysis of water

CO4 Carry out performance analysis and sizing of fuel cell for automotive application.

CO5 Devise strategies for utilizing hydrogen as fuel in IC engines.

REFERENCES:

1. Agata Godula -Jopek, “Hydrogen production: by electrolysis”, 2015, Wiley.
2. Angelo Basile and Adolfo Iulianelli, “Advances in hydrogen production, storage and distribution”, 2014, Woodhead Publishing.
3. Detlef Stolten, “Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications”, 2010, Wiley
4. Manfred Klell, Helmut Eichlseder, Alexander Trattner, “Hydrogen in Automotive Engineering”, 1st Edition, 2022, Springer Wiesbaden.
5. Efstathios-Al. Tingas, “Hydrogen for Future Thermal Engines”, 1st Edition, 2023, Springer Cham.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	2	-	3	1
2	3	1	2	-	3	-
3	3	1	2	-	3	-
4	3	1	1	-	3	-
5	3	2	3	-	3	2
Avg	3	2	-	-	3	1.5

IC3051 ADVANCED COMBUSTION TECHNOLOGIES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To provide fundamental knowledge about low temperature combustion concepts
2. To impart in-depth knowledge about various advanced LTC methods
3. To impart knowledge on fuel requirements for LTC combustion and its effect

UNIT I FUNDAMENTALS OF LOW TEMPERATURE COMBUSTION 9

Introduction, low temperature combustion (LTC) Fundamentals – Background of LTC, Principle, Benefits, Challenges, Need for control.

UNIT II GASOLINE AND DIESEL LOW TEMPERATURE COMBUSTION 9

Conventional Gasoline and Diesel Combustion, Effects of EGR, Techniques to HCCI operation in gasoline engines, Overview of diesel HCCI engines, Techniques–Early Injection, Multiple injections, Narrow angle direct injection (NADI™) concept, Modulated kinetics (MK)combustion – First and Second generation of MK combustion, RCCI combustion, Gasoline Direct Injection Compression Ignition (GDCI) combustion.

UNIT III LOW TEMPERATURE COMBUSTION CONTROL 9

Control Methods, Combustion timing sensors, HCCI/SI switching, Transition between operating modes (HCCI-SI-HCCI), Fuel effects in HCCI - gasoline, diesel, auto-ignition requirement, combustion phasing, Influence of equivalence ratio, auto-ignition timing, combustion duration, auto-ignition temperature and auto-ignition pressure, Combustion limits, IMEP and indicated efficiency, other approaches to characterizing fuel performance in HCCI engines.

UNIT IV FUEL REQUIREMENTS FOR ADVANCED COMBUSTION 9

Introduction, Background, Diesel fuel HCCI, HCCI fuel ignition quality, Gasoline HCCI, HCCI fuel specification, Fundamental fuel factors

UNIT V LTC COMBUSTION WITH ALTERNATIVE FUELS 9

Natural gas HCCI engines, CNG HCCI engines, methane/n- butane/air mixtures. DME HCCI engine - chemical reaction model, Combustion completeness, Combustion control system, Methodof combining DME and other fuels, Unmixed-ness of DME/air mixture

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Understand the fundamentals of HCCI combustion, benefits and challenges
CO2 Learn the methods followed to achieve HCCI in Gasoline and Diesel engines
CO3 Learn the HCCI combustion control methods and its significance
CO4 Understand the fuel requirements for HCCI operation and its role on complete load range operation
CO5 Learn the HCCI operation with alternative fuels and its comparison over conventional fuels

REFERENCES:

1. Hua Zhao "HCCI and CAI Engines for automotive industry" Wood Head Publishing in Mechanical Engineering, 2007.
2. Pundir B.P., Engine Combustion and Emission, 2011, Narosa Publishing House.
3. Ganesan V., "Internal Combustion Engines", 5th Edition, Tata McGraw Hill, 2012.
4. Pundir B. P., Engine Emissions" , 2nd Edition, Narosa publishing house, 2017.
5. John. B. Heywood, "Internal Combustion Engine fundamentals" McGraw – Hill, 1988.
6. HCCI Diesel Engines - NPTEL - https://nptel.ac.in/courses/112104033/34
7. HCCI and CAI Engines – NPTEL - https://nptel.ac.in/courses/112104033/33

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	1
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	1.5

IC3253 COMPUTATIONAL FLUID DYNAMICS FOR MOBILITY SYSTEMS

L	T	P	C
2	0	2	3

COURSE OBJECTIVES

1. To make the students to understand the basic principles of fluid flow, heat transfer, computational fluid dynamics (CFD) and its applications
1. To enlighten the students on the fundamental governing equations and turbulence models used in CFD solvers
2. To enable the students to understand grid generation techniques and post processing techniques.

UNIT I INTRODUCTION 6

Introduction to fluid flow and heat transfer – Mathematical description of fluid flow and heat transfer, incompressible and compressible flows, turbulent flows, boundary layer theory. Introduction to Computational Fluid Dynamics (CFD) – Objectives, modelling process, 2D and 3D simulations, advantages, limitations, application domains, software tools.

UNIT II GOVERNING EQUATIONS 6

Mass and momentum conservation equations, Energy conservation equation, Equation of state, Species transport equations, Scalar transport equations. Turbulence models – RANS, LES and DNS models.

UNIT III GRID GENERATION AND POST PROCESSING TECHNIQUES 6

Surface preparation, Volume meshing – cell types, structured, unstructured and hybrid meshing. Considerations for accurate and fast solutions. Mesh generation techniques, dynamic meshing, overset meshing, mesh size control, y+ and wall layer, adaptive mesh refinement, grid independence study. Post processing techniques – Vector plot, scalar plot, streamline plot, flow animation, x-y plot, surface area and mass flow integrated reports

UNIT IV NUMERICAL METHODS 6

Finite volume method, Discretization schemes – First order, higher order and hybrid schemes, stability of schemes. Steady and unsteady flow solvers – CG and AMG solvers, SIMPLE, SIMPLER & PISO solution algorithms. Initial and boundary conditions, material properties, solver control, convergence criteria, parallel processing.

UNIT V ADVANCED CFD SIMULATIONS 6

Compressible flow, conjugate heat transfer, VOF, MRF, porous media, radiation, combustion and emission simulations. Fluid flow and heat transfer modelling of IC engine, thermal systems, power generation and storage systems, turbomachinery etc. Introduction to fluid-structure interaction modelling

TOTAL: 30 PERIODS

LABORATORY EXPERIMENTS (30 PERIODS):

1. Prepare a closed surface geometry for a given application as per given dimensions
2. Clean-up a raw geometry for the given flow domain and mark different boundaries
3. Prepare surface mesh and volume mesh as per given size and quality criteria
4. Prepare volume meshing with different grid controls like wall layering, boundary refinement, etc.
5. Perform a simple fluid flow analysis as per given problem description
6. Perform a simple heat transfer analysis as per given problem description
7. Perform an advanced CFD analysis as per given problem description

TOTAL : 60 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

CO1 Understand the basic principles of fluid flow, heat transfer, computational fluid dynamics (CFD) and its applications

CO2 Analyse the governing equations and boundary conditions

CO3 Create grid for any simulation domain and post process various simulations

CO4 Setup solvers and perform all common simulations

CO5 Perform advance fluid flow and heat transfer simulations

REFERENCES:

1. Versteeg and Malalasekera, N, "An Introduction to computational Fluid Dynamics The Finite Volume Method," Pearson Education, Ltd., Second Edition, 2014.
2. Ghoshdastidar, P.S., "Computer Simulation of Flow and Heat Transfer", Tata McGraw-Hill Publishing Company Limited, New Delhi, 1998.
3. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, 2003.
4. Subas and V.Patankar "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation,1980.
5. Jiyuan Tu, Guan Heng Yeoh, Chaogun Liu, "Computational Fluid Dynamics A Practical Approach" Butterworth – Heinemann An Imprint of Elsevier, Madison, U.S.A., 2008
6. John D. Anderson . JR. "Computational Fluid Dynamics The Basics with Applications" McGraw-Hill International Editions, 1995.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	1	1	1	1
2	3	1	2	1	1	-
3	3	1	2	3	1	-
4	3	1	2	3	3	-
5	3	2	2	3	3	3
Avg	3	2	2	2	3	2

MB3001 OPTIMIZATION TECHNIQUES FOR MOBILITY **L T P C**
3 0 0 3

COURSE OBJECTIVE:

To provide students the knowledge of optimization techniques and approaches. Formulate a real-world problem as a mathematical model and finding solutions

UNIT I INTRODUCTION TO OPTIMIZATION TECHNIQUE 9

Introduction to optimization- Classification of Optimization - Classical Optimization Techniques- Single-Variable Optimization - Multivariable Optimization with No Constraints - Multivariable Optimization with Equality Constraints- Multivariable Optimization with Inequality Constraints- Transportation.

UNIT II NONLINEAR PROGRAMMING- I 9

One-Dimensional Minimization Methods - Unimodal Function, Elimination Methods-Unrestricted Search -Exhaustive Search - Dichotomous Search- Interval Halving Method-Fibonacci Method- Golden Section Method, Interpolation Methods - Quadratic Interpolation Method - Cubic Interpolation Method -Direct Root Methods -Newton Method Quasi-Newton Method -Secant Method.

UNIT III NONLINEAR PROGRAMMING -II 9

Unconstrained Optimization Techniques -Direct Search Methods -Indirect Search (Descent) Methods, Nonlinear Programming III: Constrained Optimization Techniques- DIRECT Methods-Indirect Methods, Geometric Programming, Dynamic Programming, Integer Programming -Integer Linear Programming - Stochastic Programming.

UNIT IV MODERN METHODS OF OPTIMIZATION 9

Genetic Algorithms -Simulated Annealing -Particle Swarm Optimization -Ant Colony Optimization -Optimization of Fuzzy Systems - Neural-Network-Based Optimization, Practical Aspects of Optimization.

UNIT V OPTIMIZATION TECHNIQUES ON MOBILITY ENGINEERING 9

Design and optimization of hybrid electric vehicle powertrain-Real-time Energy Optimization of Hybrid Electric Vehicle-Optimizing Electric Vehicle Performance-Optimization of Fuel Cell System Operating Conditions for Fuel Cell Vehicles-Optimization of the air loop system in a hydrogen fuel cell- Energy Management Strategy and Parameter Optimization of Fuel Cell Electric Vehicles.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1	Explain the fundamental knowledge of optimization techniques
CO2	Learn the Linear programming and apply it in engineering field.
CO3	Understand the Non-linear programming and apply it in mobility engineering field,
CO4	Understand the modern optimization techniques and practical aspects of optimization
CO5	Use a different optimization techniques on electric vehicle and hybrid vehicle, fuel cell for parameters optimization

REFERENCES:

1. Kalyanmoy Deb, Optimization for Engineering design – algorithms and examples. PHI, New Delhi, 2012
2. Singiresu S.Rao, "Engineering optimization – Theory and practices", John Wiley and Sons, 1998.
3. Engineering Optimization (4th Edition) by S.S.Rao, New Age International,
4. Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison-Wesley Publishers.

CO – PO MAPPING:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	2	-	-	3	3
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	3
Avg	3	2	-	-	3	3

MB3002 MACHINE LEARNING IN MOBILITY

L T P C
3 0 0 3

COURSE OBJECTIVE:

To understand the concepts of machine learning and its various algorithms and explore the different supervised and unsupervised learning techniques to adopt in mobility engineering

UNIT I INTRODUCTION AND MATHEMATICAL FOUNDATIONS 9

Machine Learning Need –History – Definitions – Applications - Advantages, Disadvantages & Challenges of Machine learning -Types of Machine Learning Problems – Mathematical Foundations - Linear Algebra & Analytical Geometry -Probability and Statistics- Bayesian Conditional Probability.

UNIT II SUPERVISED LEARNING 9

Introduction-Discriminative and Generative Models -Linear Regression - Least Squares - Under-fitting / Overfitting -Cross-Validation – Lasso Regression- Classification - Logistic Regression- Gradient Linear Models -Support Vector Machines –Kernel Methods -Instance based Methods - K-Nearest Neighbors - Tree based Methods –Decision Trees –ID3 – CART - Ensemble Methods –Random Forest.

UNIT III UNSUPERVISED LEARNING AND REINFORCEMENT LEARNING 9

Introduction - Clustering Algorithms -K – Means – Hierarchical Clustering - Cluster Validity - Dimensionality Reduction –Principal Component Analysis – Recommendation Systems - EM algorithm. Reinforcement Learning – Elements -Model based Learning – Temporal Difference Learning

UNIT IV PROBABILISTIC METHODS FOR LEARNING 9

Introduction -Naïve Bayes Algorithm -Maximum Likelihood -Maximum Apriori -Bayesian Belief Networks -Probabilistic Modeling of Problems -Inference in Bayesian Belief Networks- Clustering – Hierarchical, Partitioned clustering: K-means, PAM, eXplainable AI (XAI), Approaching an ML problem.

UNIT V MACHINE LEARNING IN MOBILITY APPLICATION 9

Wireless Battery Management System for both Hybrid Electric Vehicles and Battery Electric Vehicles-multi-mode plug-in hybrid electric vehicle- Fault mode detection of a hybrid electric vehicle and fuel cell vehicles-Cooperative energy management and eco-driving of plug-in hybrid electric vehicle-Health prediction for battery systems in real-world electric vehicles- Renewable energy and electric vehicle management for cold-climate regions- off-road hybrid electric vehicles.

TOTAL :45 PERIODS

COURSE OUTCOMES:

CO1: Understand the basic concepts of machine learning
CO2: Implement Discriminative and Generative algorithms for an application and analyze the results.
CO3: Understand the Clustering Algorithms, EM Algorithm and Reinforcement Learning
CO4: Use a tool to implement different algorithms for different types of applications
CO5: Use a different machine learning algorithms for electric vehicle and hybrid vehicle application

REFERENCES:

1. Tom Mitchell, “Machine Learning”, First Edition, Tata McGraw Hill India, 2017.
2. Hal Daumé III, “A Course in Machine Learning”, 2017 (freely available online)
3. Stephen Marsland, “Machine Learning: An Algorithmic Perspective”, Chapman & Hall/CRC, 2nd Edition, 2014.
4. Kevin Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 20123.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	2
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	2

PW3151 ELECTRIC VEHICLE CHARGING INFRASTRUCTURE LT P C

3 0 0 3

UNIT I INTRODUCTION 9

Introduction to EV Systems: Benefits of EV – Battery Charging Modes - Electric Vehicle Supply Equipment (EVSE) and its components – Classification of chargers based on charging levels : AC Slow Charger, DC Fast Charger - AC-DC Converter and DC-DC Converter for EV Charger: Types and Working Principles - Modes of charging based on IEC 61851 - Plugs and connectors - Cables: without thermal management, with thermal management - Standards related to Connectors and Communication – Challenges in Charging Infrastructure - Battery Swapping

UNIT II BUSINESS MODEL AND ELECTRICITY TARIFF STRUCTURE 9

Introduction - integrated business model - independent business model - tariff structure

UNIT III ELECTRIC DISTRIBUTION SYSTEM FOR FAST CHARGING INFRASTRUCTURE 9

Single line diagram of fast charging infrastructure - Major components of fast charging infrastructure - Single point of failure - Configuration of electric distribution considering redundancy - Other configurations

UNIT IV POWER QUALITY AND EMI/EMC CONSIDERATIONS 9

Power Quality: Impact of poor power quality from Power grid on EVSE - Impact of poor power quality from EVSE on power grid – EMI/EMC: Sources of EMI, Differential Mode Noise, Common Mode Noise, LISN, Measuring of EMI/EMC Spectrum, Design of DM filters, CM filters

UNIT V ENERGY STORAGE SYSTEMS 9

Need for Energy Storage Systems for charging infrastructure - Renewable Energy Resources and ESS for Fast Charging Infrastructure - Modes of operation - Microgrids for Charging Infrastructure

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon the successful completion of the course, students will be able to:

CO1: Design and select AC and DC chargers.

CO2: Understand and create awareness about power purchase and its tariff policy and its regulations.

CO3: Design a fast-charging infrastructure in a distribution network.

CO4: Understand the consequences of power quality issues and EMI/EMC in power grid.

CO5: Analyze the need for ESS in EVSE and ESS integrated to the microgrid.

REFERENCES:

1. Sivaraman P, Sharmeela C, Sanjeevikumar P, “Fast Charging Infrastructure for Electric and Hybrid Electric Vehicles”, First Edition, Wiley, 2023.
2. Sulab sachan, Sanjeevikumar P, Sanchari Deb, “Smart Charging Solutions for Electric and Hybrid Vehicles”, First Edition, Scrivener Publishing LLC, 2022.
3. Iqbal Husain, “Electric and Hybrid Vehicles”, Third Edition, CRC press, 2021.
4. L.Ashok Kumar, S.Albert Alexander, ”Power converters for Electric Vehicles”, First edition, CRC Press,2021.
5. Mehrdad Ehsani, Yimin Gao, Stefano Longo. Kambiz Ebrahimi,” Modern Electric, Hybrid Electric, and Fuel cell vehicles”, Third Edition, CRC Press,2019.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	-	2	3
CO2	3	1	1	-	2	3
CO3	3	1	1	-	2	3
CO4	3	1	1	-	2	3
CO5	3	1	1	-	2	3
Average	**3**	**1**	**1**	**-**	**2**	**3**

PW3052 ELECTRIC VEHICLES AND POWER MANAGEMENT **L T P C**
3 0 0 3

UNIT I HYBRID ELECTRIC VEHICLE ARCHITECTURE AND POWER TRAIN COMPONENTS 9

History of Evolution of Electric Vehicles (EV) - Comparison of Electric Vehicles with Internal Combustion Engines - Architecture of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) – Plug-in Hybrid Electric Vehicles (PHEV)- Power Train Components and Sizing, Gears, Clutches, Transmission and Brakes

UNIT II MECHANICS OF HYBRID ELECTRIC VEHICLES 9

Fundamentals of Vehicle Mechanics - Tractive Force, Power and Energy Requirements for Standard Drive Cycles of HEV's - Motor Torque - Power Rating and Battery Capacity

UNIT III CONTROL OF DC AND AC MOTOR DRIVES 9

Speed control for Constant Torque, Constant HP operation of all Electric Motors - DC/DC chopper based Four Quadrant Operation of DC Motor Drives, Inverter-based V/f Operation (motoring and braking) of Induction Motor Drives, Vector Control Operation of Induction Motor and PMSM, Brushless DC Motor Drives, Switched Reluctance Motor (SRM) Drives

UNIT IV ENERGY STORAGE SYSTEMS 9

Battery: Principle of operation, Types, Estimation Of Parameters, Battery Modeling, SOC of Battery, Traction Batteries and their capacity for Standard Drive Cycles, Vehicle to Grid operation of EV's -Alternate sources: Fuel cells, Ultra capacitors, Fly wheels

UNIT V HYBRID VEHICLE CONTROL STRATEGY AND ENERGY MANAGEMENT 9

HEV Supervisory Control - Selection of modes - Power Spilt Mode - Parallel Mode - Engine Brake Mode - Regeneration Mode - Series Parallel Mode - Energy Management of HEV's

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of the course, students will be able to:

CO1: Learn the electric vehicle architecture and power train components.

CO2: Acquire the concepts of dynamics of Electrical Vehicles.

CO3: Understand the vehicle control for Standard Drive Cycles of Hybrid Electrical Vehicles (HEVs).

CO4: Ability to model and understand the Energy Storage Systems for EV.

CO5: Acquire the knowledge of different modes and Energy Management in HEVs.

REFERENCES:

1. Iqbal Husain, “Electric and Hybrid Electric Vehicles”, First Edition, CRC Press, 2011
2. Wei Liu, “Hybrid Electric Vehicle System Modeling and Control”, Second Edition, Wiley, 2017
3. James Larminie and John Lowry, “Electric Vehicle Technology Explained”, Second Edition, 2012
4. Mehredad Ehsani, Yimi Gao, Stefano Longo and Kambiz Ebrahimi,” Modern Electric, Hybrid Electric and Fuel cell Vehicles”, Third edition, CRC Press, 2019
5. Jingsheng Yu and Vladimir V. Vantsevich, “Control Application of Vehicle Dynamics”, First Edition, CRC Press, 2021

MAPPING OF COs WITH POs AND PSOs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	-	3
CO2	3	1	2	1	-	3
CO3	3	1	2	1	-	3
CO4	3	1	2	1	-	3
CO5	3	1	2	1	-	3
Average	**3**	**1**	**2**	**1**	**-**	**3**

PW3059	ELECTRICAL DRIVES AND CONTROL	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To expose the students to the fundamentals of electric drives systems and their components
2. To understand AC and DC drives, and to model and control them

UNIT I INTRODUCTION 9

Concepts, and classification of Electric drives - Selection of motors - Dynamics of Electric drives: Types of loads, Multi quadrant operations, motor dynamics steady state stability and transient stability - Rating and Heating of motors: Heating effects, heating and cooling curves - classes of duty - load equalization.

UNIT II POWER SEMICONDUCTOR DEVICES 9

Construction and Characteristics of Power Diodes, BJT, SCR, TRIAC, MOSFETs, and IGBT- Half wave rectifier – mid-point secondary transformer based full wave rectifier – bridge rectifier- distortion factor – capacitor filter for low power rectifiers – LC filters – Concern for power quality – three phase Diode Bridge.

UNIT III DYNAMIC MODELING OF ELECTRIC MACHINES 9

Construction and types of Electric motors - Development of dynamic equations of DC motor - derivation of dynamic equations of three phase AC machine (only cylindrical rotor), SRIM and PMSM - development of steady state machine models (equivalent circuit) from the dynamic equations

UNIT IV DC MOTOR DRIVES 9

Basic characteristics - Single phase and three phase controlled rectifier fed DC drives -Dual converters drives - Chopper drives - Rheostat and regenerative braking - effects of changes in supply voltage and load torque - closed loop control schemes.

UNIT V AC MOTOR DRIVES 9

Induction motor drives - Voltage Source Inverter and its PWM strategies - stator voltage control - stator impedance control, rotor voltage control - Slip power recovery, FOC, DTC, Sensorless control - Dynamic, plugging, and regenerative breaking - Need for harmonic filter.
Control of Synchronous motors, Brushless DC motor, Permanent Magnet Synchronous motor, and Synchronous Reluctance Motor.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

On successful completion of this course the student will be able to

- **CO1** Gain fundamental knowledge on electric motors and power electronics
- **CO2** Acquire and develop knowledge on control systems
- **CO3** Gain knowledge on drive system architecture and components
- **CO4** Explore real-world applications of electrical drives and control systems across various industries
- **CO5** Develop and design controlled electrical drives & control systems to ensure system stability and reliable operations

REFERENCES:

1. G.K. Dubey, Fundamentals of Electric Drives, , 2nd Edition, Narosa publishing House, 2010
2. V Subrahmanyam, Electric Drives, 2nd Edition, McGrawhill Education, 2010
3. R. Krishnan, "Electric Motor Drives-Modeling, Analysis, and Control", Prentice Hall India, 2001
4. Rashid M.H., Power Electronics Circuits, Devices and Applications, Prentice Hall India, 3 rd Edition, New Delhi, 2004.
5. Ned Mohan, T.M.Undeland, W.P.Robbins,"Power Electronics: Converters, applications and design", John Wiley and Sons, 3rd Edition (reprint), 2009.
6. PhilipT.Krein, Elements of Power Electronics, Oxford University Press, 2013. 4. P.C.Sen, Power Electronics, Tata McGraw-Hill, 30th reprint, 2008.

CO – PO MAPPING:

CO	PO					
	1	2	3	4	5	6
1	3	2	-	-	3	1
2	3	1	-	-	3	-
3	3	1	-	-	3	-
4	3	1	-	-	3	-
5	3	2	-	-	3	2
Avg	3	2	-	-	3	1.5

ET3252 EMBEDDED CONTROL FOR ELECTRIC DRIVES L T P C

2 0 2 3

UNIT I INTRODUCTION ELECTRICAL DRIVES 6

Electric drive and its classifications, Four-quadrant drive, Dependence of load torque on various factors, Dynamics of motor-load combination-Solid State Controlled Drives-Machine learning and optimization techniques for electrical drives- IoT for Electrical drives applications.

UNIT II EMBEDDED PROCESSOR 6

Embedded Processor architecture - RTOS - Hardware/software co-design Programming and optimization with SoC processors - control algorithms implementation for power converter.

UNIT III INDUCTION MOTOR CONTROL 6

Types - Speed control methods - PWM techniques- VSI fed three - phase induction motor- Fuzzy logic Based speed control for three phase induction motor - FPGA based three phase induction motor control.

UNIT IV BLDC MOTOR CONTROL 6

Overview of BLDC Motor - Speed control methods - PWM techniques - ARM processor based BDLC motor control - ANN for BLDC Motor control and operation.

UNIT V SRM MOTOR CONTROL 6

Overview of SRM Motor - Speed control methods - PWM techniques - FPGA based SRM motor control - DNN for SRM Motor control and operation.

30 PERIODS

SKILL DEVELOPMENT ACTIVITIES (Hands on laboratory practice / Seminar/ Mini Project/etc)
30 PERIODS

1. Laboratory exercise: Use any System level simulator/MATLAB/open-source platform to give hands-on training on simulation study on Electric drives and control.
   a. Simulation of four quadrant operation and speed control of DC motor
   b. Simulation of 3-phasee inverter.
   c. Simulation of Speed control of Induction motor using any suitable software package.
   d. Simulation of Speed control of BLDC motor using any suitable software package.
   e. Simulation of Speed control of SRM using any suitable software package
2. Seminar: IoT-based Control and Monitoring for DC Motor/ any Electric drives.
3. Mini project.: Any Suitable Embedded processor-based speed control of Motors (DC/IM/BLDC/PMSM/SRM)

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of this course, the students will have the ability to

CO1: Interpret the significance of embedded control of electrical drives

CO2: Deliver insight into various control strategy for electrical drives.

CO3: Developing knowledge on Machine learning and optimization techniques for motor control.

CO4: Develop embedded system solution for real time application such as Electric vehicles and UAVs.

CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded system skills required for motor control strategy.

REFERENCES:

1. R.Krishnan, “Electric Motor Drives - Modeling, Analysis and Control”, Prentice-Hall of India Pvt. Ltd., New Delhi,2010.
2. Vedam Subramanyam, “Electric Drives - Concepts and Applications”, Tata McGraw-Hill publishing company Ltd., New Delhi, 2002
3. K. Venkataratnam, “Special Electrical Machines”, Universities Press, 2014.
4. Steve Furber, “ARM system on chip architecture”, Addision Wesley,2010.
5. Ron Sass and AnderewG.Schmidt, “Embedded System design with platform FPGAs: Principles and Practices”, Elsevier, 2010.
6. Steve Kilts, "Advanced FPGA Design: Architecture, Implementation, and Optimization" Willey, 2007.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	2	-	2	-
CO2	1	1	3	-	-	2
CO3	2	-	-	-	3	-
CO4	1	2	3	1	-	-
CO5	-	-	-	-	3	-
Average	**1.66**	**1.5**	**2.7**	**1**	**2.7**	**2**