NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

M.TECH – Automobile Engineering

SCHEME OF INSTRUCTION AND SYLLABI

for M.Tech. Automobile Engineering Programme

(Effective from 2021-22)

DEPARTMENT OF MECHANICAL ENGINEERING

Vision and Mission of the Institute

National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society.

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Department of Mechanical Engineering

VISION

To be a global knowledge hub in mechanical engineering education, research, entrepreneurship and industry outreach services.

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Department of Mechanical Engineering:

Brief about the Department:

The Department of Mechanical Engineering was established in the year 1959. The department presently offers one Under Graduate Programme, i.e., B.Tech in Mechanical Engineering with an intake of 170 students, seven M.Tech programmes - Thermal Engineering, Manufacturing Engineering, Computer Integrated Manufacturing , Machine Design, Automobile Engineering, Materials and Systems Engineering Design, Additive Manufacturing - and Ph.D programmes. At present, the Department has 48 faculty members with research expertise in different specializations of Mechanical Engineering. The Department has good research facilities for both experimental as well as simulation-based research. The department has liaison with reputed industries and R&D organizations such as NFTDC, DMRL, DRDL, ARCI, BHEL, CPRI etc. All the faculty of the department are actively engaged in R&D and Consultancy. Presently the department is handling about 25 funded projects worth Rs. 3.00 Crores. The department has recently acquired metal 3D printer at a cost of Rs.1.4 Crores under TEQIP -III grants. The institute is establishing SIEMENS Centre of Excellence in digital twin Industry 4.o in manufacturing in which the department is playing key role in the execution of the project. The department produces a large number of publications, and offers solutions to the industry regularly and is also active with regular outreach activities like workshops, conferences and executive programmes for industry personnel. The department has been recognized as QIP Centre for M.Tech and Ph. D. programmes.

List of Programmes offered by the Department:

Program	Title of the Programme
B.Tech.	Mechanical Engineering
M.Tech.	Thermal Engineering
	Automobile Engineering
	Manufacturing Engineering
	Machine Design
	Computer Integrated Manufacturing
	Materials and Systems Engineering Design
	Additive Manufacturing
PG Diploma	Additive Manufacturing
Ph.D.	Mechanical Engineering

Note: **Refer to the following weblink for Rules and Regulations of M.Tech. program:**
https://www.nitw.ac.in/main/MTechProgram/rulesandregulations/

DEPARTMENT OF MECHANICAL ENGINEERING

M.Tech. – Automobile Engineering

Programme Educational Objectives (PEOS)

Programme Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the programme is preparing graduates to achieve. They are consistent with the mission of the Institution and Department. Department faculty members continuously worked with stakeholders (local employers, industry and R&D advisors, and the alumni) to review the PEOs and update them periodically.

PEO-1	Apply concepts of engineering to analyze automotive systems.
PEO-2	Develop innovative automotive technologies to address specific needs of performance, comfort, safety and eco-friendliness.
PEO-3	Apply computational tools for comprehensive understanding of the complex systems in automotive engineering.
PEO-4	Communicate effectively and support constructively towards team work.
PEO-5	Engage in lifelong learning for career and professional growth with ethical concern for society and the environment.

Programme Articulation Matrix

PEO / Mission Statements	PEO1	PEO2	PEO3	PEO4	PEO5
Impart quality education and training to nurture globally competitive mechanical engineers.	3	2	3	2	3
Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge.	3	3	2	2	3
Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.	2	2	2	2	3

1-Slightly; 2-Moderately; 3-Substantially

M.Tech. – Automobile Engineering

Programme Outcomes (POs) are narrower statements that describe what the students areexpected to know and be able to do upon the graduation. They relate the knowledge, skills and behaviour of the students acquire through the programme. The Program Outcomes (PO) are specific to the programme and facilitate the attainment of PEOs.

PO-1	Carryout independent research/investigation and development work to solve practical problems.
PO-2	Write and present a substantial technical report/document.
PO-3	Demonstrate a degree of mastery in automobile engineering at a level higher than the Bachelor's programme.
PO-4	Apply engineering knowledge, state-of-the-art tools and techniques to design and analyze automobile systems and sub-systems.
PO-5	Evaluate prime movers and analyze vehicle on-road performance.
PO-6	Engage in lifelong learning adhering to professional, ethical, legal, safety, environmental and societal aspects for career excellence.

Mapping of Programme Outcomes With Programme Educational Objectives

PO / PEO	PO1	PO2	PO3	PO4	PO5	PO6
PEO1	3	3	2	3	3	2
PEO2	3	2	2	3	2	2
PEO3	2	2	2	2	3	2
PEO4	2	2	2	2	2	3
PEO5	3	2	3	3	3	3

1-Slightly; 2-Moderately; 3-Substantially

Credits in Each Semester

Category	I Year, Sem – I	I Year, Sem – II	II Year, Sem – I	II Year, Sem – II	Total No. of credits to be earned
Core courses	12	06	--	--	**18**
Electives	06	12	--	--	**18**
Lab Courses	04	04	--	--	**08**
Comprehensive Viva-Voce	--	--	02	--	**02**
Seminar	01	01	--	--	**02**
Dissertation	--	--	12	20	**32**
Total	**23**	**23**	**14**	**20**	**80**

SCHEME OF INSTRUCTION

M.Tech. Automobile Engineering – Course Structure

I - Year, I – Semester

S. No.	Course Code		L	T	P	Credits	Cat. Code
1	ME5501	Automotive Engineering	3	0	0	3	PCC
2	ME5502	Computational Methods in Automobile Engineering	3	0	0	3	PCC
3	ME5503	Vehicle Body Engineering	3	0	0	3	PCC
4	ME5504	Prime Movers for Automobiles	3	0	0	3	PCC
5		Elective-1	3	0	0	3	PEC
6		Elective-2	3	0	0	3	PEC
7	ME5505	Automotive Engines Laboratory	0	1	2	2	PCC
8	ME5506	Geometric Modeling and Automation	0	1	2	2	PCC
9	ME5548	Seminar-I	0	0	3	1	SEM
		Total	**18**	**2**	**7**	**23**	

I - Year, II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5551	Automotive Electronics	3	0	0	3	PCC
2	ME5552	Vehicle Dynamics	3	0	0	3	PCC
3		Elective-3	3	0	0	3	PEC
4		Elective-4	3	0	0	3	PEC
5		Elective-5	3	0	0	3	PEC
6		Elective-6	3	0	0	3	PEC
7	ME5553	Automotive Systems laboratory	0	1	2	2	PCC
8	ME5554	Engineering Analysis and Simulation Laboratory	0	1	2	2	PCC
9	ME5598	Seminar-II	0	0	3	1	SEM
		Total	**18**	**2**	**7**	**23**	

Note: PCC – Professional Core Courses
PEC – Professional Elective Courses

SCHEME OF INSTRUCTION

M.Tech. Automobile Engineering – Course Structure

II - Year, I – Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6547	Comprehensive Viva – Voce	2	CVV
2	ME6549	Dissertation - Part A	12	DW
		Total	**14**	

II - Year, II – Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6599	Dissertation - Part B	20	DW
		Total	**20**	

Note: PCC – Professional Core Courses

List of Professional Elective Courses (M.Tech – Automobile Engineering)

I - Year, I – Semester

S. No.	Course Code	Course Title
Programme Specific Professional Elective Courses		
1	ME5511	Noise, Vibrations & Harshness
2	ME5512	Thermo-Fluid Engineering for Automobiles
3	ME5513	Alternate Fuels and Emissions
4	ME5514	Engine Management Systems
Elective Courses from MTech Thermal Engineering		
1	ME5113	Renewable Sources of Energy
2	ME5114	Energy Systems and Management
Elective Courses from MTech Materials and Systems Engineering Design		
1	ME5613	Mechanics of Metal Forming
Elective Courses from MTech Computer Integrated Manufacturing		
1	ME5311	Enterprise Resource Planning
2	ME5312	Manufacturing Management
3	ME5313	Soft Computing Techniques
Elective Courses from MTech Machine Design		
1	ME5404	Computer-Aided Geometric Design
2	ME5412	Characterization of Engineering Materials
3	ME5413	Analysis and Synthesis of Mechanisms

List of Professional Elective Courses (M.Tech – Automobile Engineering)

I - Year, II – Semester

S. No.	Course Code	Course Title
Programme Specific Professional Elective Courses		
1	ME5561	Fuel Cell Technology
2	ME5562	Vehicle Testing and Instrumentation
3	ME5563	Automotive Safety and Maintenance
4	ME5564	Hybrid Electric Vehicles
Elective Courses from M.Tech Thermal Engineering		
1	ME5162	Advanced Computational Fluid Dynamics
2	ME5166	Design of Heat Transfer Equipment
3	ME5170	Essentials of Entrepreneurship
4	ME5171	Combustion and Emission control
Elective Courses from M.Tech Materials and Systems Engineering Design		
1	ME5664	Non-Destructive Testing and Evaluation
Elective Courses from M.Tech Computer Integrated Manufacturing		
1	ME5367	Reliability Engineering
2	ME5368	Industry 4.0 and IIoT
3	ME5369	Design and Analysis of Experiments
4	ME5370	Project Management
5	ME5371	AI and ML for Mechanical Systems
Elective Courses from M.Tech Machine Design		
1	ME5462	Condition Monitoring and Fault Diagnostics
2	ME5466	Tribology in Design
3	ME5467	Advanced Composite Technologies
4	ME5469	Optimization Methods for Engineering Design
Elective Courses from M.Tech Manufacturing Engineering		
1	ME5265	Mechatronics and Robotics
2	ME5266	Precision Manufacturing
Elective Courses from M.Tech Additive Manufacturing		
1	ME5763	Re-Engineering

DETAILED SYLLABUS

M.Tech. – Automobile Engineering

I- Year, I- Semester

Course Code: ME5501	AUTOMOTIVE ENGINEERING	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify the systems and sub-systems of a typical automobile
CO2	Analyze prime movers based on their configuration
CO3	Examine advanced cooling, lubrication, power transmission systems and components
CO4	Interpret advanced concepts in Steering, Suspension and Braking systems
CO5	Adapt recent innovations in automobile sector like wheels, tires, air conditioning and lighting.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO	2	2	2	2	2	1
CO	2	2	3	3	3	1
CO	2	2	3	2	2	1
CO	2	2	3	3	1	1
CO	2	2	3	2	1	3

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, History of Automobiles, Classification of Automobiles.

Ignition, Lubricating and cooling systems: Types of ignition system, electronic ignition system, components of ignition system, starting system, Functions & properties of lubricants, methods of lubrication-splash type, pressure type, dry sump, and wet sump & mist lubrication. Oil filters, oil pumps, oil coolers. Characteristics of an effective cooling system, types of cooling system, radiator, thermostat, air cooling & water cooling.

Automotive air conditioning: ventilation, heating, air condition, refrigerant, compressor and evaporator.

Clutch: Function, operation, types, relative merits, clutch linkages**,** design problems**, Transmission (gear box)-** function, working, types, gear shift mechanism, limitation of manual transmission, epicyclic gear train, automatic transmission, design problems, **propeller shafts,** drive line types**, differential, front and rear axles,** rear axle mountings**.**

Steering System: wheel geometry, functions of steering mechanism, steering gear box types, power steering systems.

Braking and suspension system: functions and classification of brakes, operation of brake actuation mechanism, disc brakes, constructional and operation of ABS, Types of springs shock observers, objectives and types of suspension system, rear axles suspension, independent suspension system.

Wheels and tyres: Wheel assembly, types of wheels, wheel rims. Construction of tyre, tyre treads and tyre specifications

Learning Resources:

Text Books:

1. Automotive Mechanics, Joseph Heitner, CBS publications, Second edition, 2015
2. Automotive Mechanics, Srinivasan, S, 2nd Edition, Tata McGraw- Hill, 2018
3. Automobile Engineering. By K.M.Gupta.l, Vol.I & II, Umesh Pub, 2012.

Reference Books:

1. Automotive Mechanism, Crouse and Anglin, 9th Edition. Tata McGraw-Hill, 2017
2. A Systems Approach to Automotive Technology, Jack Erjavec, Cengage LearningPub 2009.

Course Code: ME5502	COMPUTATIONAL METHODS IN AUTOMOBILE ENGINEERING	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand the Finite Element Formulation procedure for automotive structures.
CO2	Analyse the structural and dynamic response of automotive components.
CO3	Solve thermal and fluid flow problems of automotive applications
CO4	Analyse the coupled Fluid-Structure interaction problems in Automotive Engineering

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	1
CO2	2	2	2	3	3	1
CO3	2	3	3	3	3	1
CO4	1	2	3	3	2	1

Syllabus:

Introduction: Historical Perspective of Computational methods in automobile engineering, A brief review on steady state, propagation and transient problems in engineering analysis, Need of Finite Element and Finite Volume methods and their applicability to various structural, heat transfer and fluid flow problems in Automotive Engineering, Comparison of FDM, FEM, FVM, Advantages and limitations of FEM and FVM, A brief discussion on Commercial FEM and FVM packages for Automotive Engineering.

Approximate Solutions of BVP: Need of Approximate Solutions of BVP and their accuracy with respect to Analytical Solutions, Various Boundary Conditions of BVP, Strong and weak forms of General BVP, Weighted Residual Methods (Least Squares Method, Collocation Method, Galerkin Method, Modified Galerkin Methods), Energy or Variational Methods.

Finite Element Formulation: Basic Finite Element Concepts, General finite element solution procedure, Concept of discretisation, Interpolation, Formulation of Finite element characteristic matrices and vectors, Compatibility, Assembly and boundary considerations.

1D Elements for Structural Problems: Axial deformation in bars and Springs, Formulation of stiffness matrix, FE Formulation for Truss elements, Global, Local and Natural coordinates, Plane truss and Space truss, Stresses due to lack of fit and temperature changes, FE Formulation for Beam elements, Calculation of stresses in beams, Thermal stresses in beams, Plane Frame and Space frames, Thermal stresses in frames, General 1D BVP and its applications (Heat Transfer, Fluid Mechanics, Column Buckling), Introduction to higher order elements, Shape functions for higher order problems, Iso-parametric mapping, Advantages and disadvantages of higher order elements.

2D Elements for Structural Problems: Solution of 2D BVP with triangular and quadrilateral elements, Numerical integration schemes, Iso-Parametric elements, Applications of 2D BVP

(Ideal fluid flow around an irregular object, Two dimensional steady state heat flow, Torsion of prismatic bars), 2D Elasticity (Plane stress and Plane strain), Axisymmetric elasticity problems, Introduction to 3D Elements.

Structural and Dynamic Analysis: 1D & 2D dynamic problems in Solid mechanics, Dynamics problems representation in FE, Free vibration problem formulation, Torsion of non-circular shaft - axisymmetric problem

Thermal analysis: Review of basic equations of steady and transient heat conduction, 1D & 2D problems in conduction heat transfer

Finite elements in flow problems: Review of basic equations of convection dominated flows, Solutions through Galerkin approximation for convection dominated flows, Babuška–Brezzi Condition, Need of Stabilization in Convection dominated flows.

Finite Volume Method and Fluid-Structure Interaction: A brief introduction to Finite Volume Method for fluid flow problems, Advantages and Limitations of FVM over FEM for flow problems, Discretization of Navier-Stokes Equation through FVM, Coupled FE and FV analyses for Fluid-Structure Interaction problems, Arbitrary Lagrangian-Eulerian description, One-way and two-way coupling, Applications of FSI in automotive systems.

Learning Resources:

Text Books:

1. Fundamental Finite Element Analysis and Applications: with Mathematica and Matlab Computations, Bhatti, M.A., Wiley, 2005.
2. Finite Element Procedures in Engineering Analysis, Klaus-Jürgen Bathe, Prentice-Hall, 1982
3. Finite Element Method in Engineering, Reddy, J.N., Tata McGraw Hill, 2007.

Reference Books:

1. Applied Finite Element Analysis, Larry J. Segerlind, 2nd Edition, Wiley.
2. The Finite Element Method: Its Basis and Fundamentals, J. Z. Zhu, Olgierd Zienkiewicz, and Richard Taylor, Sixth Edition, Elsevier, 2005.

Online Resources:

1. Finite Element Analysis by Prof. B.N Rao (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/105/106/105106051/)
2. Finite Element Procedures for Solids and Structures by Prof. Klaus-Jürgen Bathe (MIT Massachusetts), MIT OpenCourseware (Link: https://ocw.mit.edu/resources/res-2-002-finite-element-procedures-for-solids-and-structures-spring-2010/)

Course Code: ME5503	VEHICLE BODY ENGINEERING	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Classify vehicle body according to body shape and frame structures.
CO2	Analyse the aerodynamic forces acting on the vehicle body to reduce drag.
CO3	Apply the principles of simple structural surface method to strengthen vehicle body panels.
CO4	Examine the vehicle crash testing methods
CO5	Identify sources of noise and the methods to minimize it.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	3	2	2
CO2	1	2	2	3	2	1
CO3	2	1	3	3	3	2
CO4	3	1	3	3	2	3
CO5	2	1	3	3	1	2

Syllabus:

Frame: Introduction, Loads on the Frames, Construction and Cross sections of the frame, Types of Frames.

Automotive Body: Vehicle body styles, Aerodynamic considerations in body profiling: Drag reduction, Drag force calculation.

Vehicle Structure: Basic requirement of stiffness and strength, Vehicle structure types, Demonstration of Simple Structural Surfaces (SSS).

Body Components: Bumpers, Grilles, Sill covers and side air-dams, outer moldings, Weather strips, Glass and Mirrors, Doors

Body Interiors: Seat Belt Restraint system - Airbag, components of Airbag, Dash Board

Vehicle Safety: Introduction, Crash testing, protection of occupants, Testing for occupants safety, safety controls.

Noise: Interior noise - Engine noise, Road noise, wind noise, brake noise, Noise Assessment and control

Learning Resources:

Text Books:

1. Vehicle Body Engineering, Powloski J, Business Books Ltd, 2000.
2. Automotive Body, Volume-I (component design), Lorenzo Morello, Springer, 2013
3. Automotive Engineering (Power Train, Chassis system and Vehicle Body), David A Crolla, Elsevier collection, 2009.

Reference Books:

1. Body Construction & Design, Giles G.J. Illiffe Books Butter worth & co., 2000.
2. Vehicle Body Layout and Analysis, John Fenton, Mechanical Engineering Publication Ltd., London, 2001.

Course Code: ME5504	PRIME MOVERS FOR AUTOMOBILES	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand the importance of IC engine as a prime mover and compare its performance on the basis of thermodynamic cycles, and combustion process.
CO2	Identify harmful IC engine emissions, examine the advances in combustion concepts, injection systems and use viable alternate fuels.
CO3	Classify alternate power sources for automobiles.
CO4	Analyse and evaluate the configurations of battery, hybrid and fuel cell electric vehicles.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	2
CO2	3	2	2	3	3	2
CO3	2	2	3	2	3	2
CO4	2	2	3	2	2	2

Syllabus:

Introduction to IC engines: Classification of Prime Movers; IC Engines as Prime Movers; Historical Perspective of IC Engines; IC Engines-Classification, Mechanical cycle and Thermodynamic cycle, Air standard cycles-Diesel, Otto, Dual and Miller cycles. Differences between 2-stroke and 4-stroke cycle engines, Differences between SI and CI engines.

Combustion in SI and CI Engines: ***SI Engines:*** Brief treatment on Flame Propagation-Combustion phenomena (Normal and Abnormal), Factors affecting, Detonation, Ignition quality(Octane rating), Requirements of good combustion Chamber-Types, HUCR; ***CI Engines:*** Importance of air motion and Compression Ratio, Mixture Preparation inside the CC. Normal and abnormal combustion - Ignition Quality (Cetane rating) ; Characteristics of a Good Combustion Chamber- Classification of Combustion Chambers (DI and IDI).

Fuel Metering in SI and CI Engines: Brief treatment on Carburetion and fuel injection systems for SI Engines; Types of Fuel injection Systems - Individual, Unit and Common Rail (CRDI), Fuel Injectors-Nozzle types, Electronic Control Unit (ECU)-Numerical problems on fuel injection.

Supercharging of IC Engines: Need of Supercharging and advantages, Configurations of Supercharging-Numerical problems on turbocharging.

Pollutant emissions from IC Engines: Introduction to clean air, Pollutants from SI and CI Engines: Carbon monoxide, UBHCs, Oxides of nitrogen (NO-NOX) and Particulate Matter. Mechanism of formation of pollutants, Factors affecting pollutant formation. Brief treatment on Measurement of engine emissions-instrumentation and pollution Control Strategies, Emission norms-EURO and Bharat stage norms.

Performance of IC Engines: Classification of engine performance parameters- Measurement of brake power, indicated power and friction power. Engine and Chassis dynamometers, driving cycles, Factors affecting performance, Heat loss, Air-fuel ratio, Energy Balance: Pi and Sankey diagrams Numerical problems.

Advances in IC Engines: New combustion concepts- Stratified Charge Engines, HCCI, PCCI and RCCI. New injection concepts-port fuel injection and gasoline direct injection systems.

Alternate Fuels: Need for Alternate fuels, Desirable Characteristics of a good Alternate Fuel- Liquid and Gaseous fuels for SI and CI Engines, LPG, Alcohols, Bio-fuels, Natural Gas and Hydrogen. Brief treatment on production and use of alternate fuels in IC Engines.

Batteries: Battery: Battery parameters; Types of batteries- Technical characteristics-Ragone plots.

Electric Vehicles: Introduction: History of EVs, EV system, basic structure- Electric vehicle drive train-advantages and limitations, Components of EV Battery run EVs and Electric Motor run EVs- Brief treatment on types of electric machines for EVs (Power-Torque characteristics), regenerative braking system.

Hybrid Vehicles: Configurations of hybrids, advantages and limitations- basic structure of series, parallel and series-parallel configurations, Power-Torque characteristics. Hydrogen: Production-Hydrogen storage systems-reformers.

Fuel Cell vehicles: Introduction-Fuel cell characteristics, Fuel cell types: Brief introduction to PEMFC and DMFCs.

Learning Resources:

Text Books:

1. Internal Combustion Engine Fundamentals, John.B. Heywood , McGraw Hill Co.2018, II Edition.
2. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi, CRC Press, 2018, II Edition.

Reference Books:

1. Engineering Fundamentals of IC Engine, W.W. Pulkrabek , PHI Pvt.Ltd 2002 II Edition
2. Electric vehicle technology explained, John Lowry and James Larmine, John Wiley and Sons, 2012.
3. PEM Fuel Cells-Theory and Practice, Frano Barbir, Elsevier Academic Press, 2005.

Online Resources:

1. Introduction to Hybrid and Electric vehicles by Dr. Praveen Kumar and Prof. S. Majhi (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/108/103/108103009/)

Course Code: ME5505	AUTOMOTIVE ENGINES LABORATORY	Credits 0-1-2: 2

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify the systems and sub-systems of IC engines
CO2	Determine properties of a given fuel/oil sample and identify fuel/oil for specific use
CO3	Analyze the performance and emissions of SI and CI Engines by experimentation
CO4	Understand the engine and vehicle electrical circuit.

Course Articulation Matrix:

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

Syllabus:

S. No	Exercise
1	Motoring and retardation test on a Single Cylinder Diesel Engine with DC shunt Dynamometer
2	Morse test on a Multi Cylinder Petrol Engine
3	Heat Balance Test on a Single Cylinder Diesel Engine with Water brake Dynamometer
4	Determination of Fuel properties with the apparatus available in the Laboratory
5	Conduct of experiment on Computerized single cylinder diesel engine to determine performance, Heat balance, Exhaust emissions and ~~temperatures~~
6	Performance of VCR Engine with variable fuel injection pressure.
7	VCR Engine emission measurement.
8	Performance Characteristics of Lead Acid battery
9	Demonstrate of automotive wiring circuits.(level-I Engine)
10	Demonstrate of automotive wiring circuits.(level-II Vehicle)

Learning Resources:

Text Books:

1. Fundamentals of Internal Combustion Engines, H.N.Gupta, PHI publication, 2015.
2. Internal Combustion Engine Fundamentals, J.B. Heywood, McGraw Hill Co.2018
3. Engineering Fundamentals of IC Engine, W.W. Pulkrabek, PHI Pvt.Ltd 2002

Course Code: ME5506	GEOMETRIC MODELLING AND AUTOMATION	Credits 0-1-2: 2

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Express vehicle components using 2D or 3D digital sketches
CO2	Model a component with free-form surfaces
CO3	Model an assembly component with kinematic linkages
CO4	Identify and resolve issues in CAD Data Exchange
CO5	Apply design automation techniques for engineering analysis and design verification

Course Articulation Matrix:

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

Syllabus:

Introduction to CAD and working on user Interface for Geometric modelling of vehicle components like Piston, IC Engine, chassis, shape of car body etc.

Sketching Techniques:

- Construction of 1D &2D entities like line, curve, polygon.
- Editing or modifying these entities using operations like filleting, chamfer, offset.
- Use transformation techniques like translate, rotate, scale, Mirror, pattern to build desired model.

3D Part Modelling:

- Create 3D Model (Surface or Solid Model) by using form features like Extrude, Revolve, Loft.
- Apply transformation techniques and Boolean operations like Union, Difference and Intersection to build complex models.
- Apply appropriate Geometric Dimension and Tolerance to the 3D Model.
- Create an assembly model using 3D Parts based on appropriate configuration and constraints.

- Use editing features to modify the final 3D model using its construction history.
- Create a Blue-print Drawing of the final 3D Model for manufacturing.
- Reverse Engineering Technique: 3D reconstruction of Part from the given Point Cloud data.

Automation Techniques:

- Geometric Reasoning Operators: Given a 3D model, query it's curvature information, properties like length, mass, volume, moment of inertia, and detect clash among multi-bodies.
- Introduction to CAD Data Exchange, automatic repairing or healing of 3D CAD model to build valid 3D model; automatic extraction of various form features (Holes, Extrusion, Fillet etc.) from the standard Boundary Representation Models (IGES, STEP).
- Brief introduction to Engineering Analysis, Apply Automated (like triangulations techniques) or Semi-Automated (like hexahedral mesh generation) mesh generation methods to a given 3D Model for Engineering Analysis.
- Automatic Verification & Validation of manufactured Part from scanned data using soft Metrology techniques like Point Cloud Registration & Comparison, fitting primitives like Planes, Sphere etc.

Learning Resources:

Reference Books:

1. Principles of CAD/CAM/CAE, Kunwoo Lee, Pearson, 1999.

Online Resources:

1. CREO Documentation https://support.ptc.com/help/creo/creo_pma/usascii/
2. Cloud Compare http://www.cloudcompare.org/doc/qCC/CloudCompare%20v2.6.1%20-%20User%20manual.pdf
3. Autodesk Self-Paced Tutorials https://help.autodesk.com/view/fusion360/ENU/courses/
4. Autodesk Product Documentation https://help.autodesk.com/view/fusion360/ENU/?guid=GUID-1C665B4D-7BF7-4FDF-98B0-AA7EE12B5AC2

Course Code: ME5548	SEMINAR-I	Credits 0-0-3: 1

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify and compare technical and practical issues related to the area of course specialization.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of technical writing and critical thinking
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	1	2
CO2	3	3	2	2	2	3
CO3	3	3	2	2	2	2
CO4	3	2	2	2	2	2

Evaluation Scheme:

Task	Description	Weightage
I	Clarity on the topic	10
II	Literature survey	30
III	Content	30
IV	Presentation	20
V	Response to Questions	10
TOTAL		**100**

Task CO-PO mapping:

Task/CO	CO1	CO1	CO1	CO1
I	X			
II		X		
III			X	
IV				X
V				X

I-Year, II Semester

Course Code: ME5551	AUTOMOTIVE ELECTRONICS	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand the electronic circuit fundamentals, safety and basic test equipment.
CO2	Analyze vehicle electronic circuits.
CO3	Outline the working of batteries, starting systems, charging systems, ignition systems and auxiliaries.
CO4	Analyze the performance of sensors and ECU.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	2	1	1
CO2	2	1	3	3	2	2
CO3	1	1	2	2	1	1
CO4	1	1	2	2	1	1

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, History of Automotive electronics. Circuit fundamentals**:** voltage, current**,** resistance, circuits components, series and parallel circuits in vehicles, basic test equipment: voltmeters, ammeters, ohmmeter, Digital Storage Oscilloscope

Electronic fundamentals: Basic principles of semiconductor technology, electronic control input devices, Passive components, Semiconductor components, Manufacture of semiconductor components and circuits

Wiring diagrams and Batteries: wiring diagram symbols, using the wiring diagram, automotive batteries, diagnosing batteries, servicing batteries.

Electrical and electronic systems in the vehicle:. Motronic-engine management system, Electronic diesel control (EDC), Lighting technology, defogger, horn, and windshield wiper circuits, diagnosing defogger, horn, and windshield wiper circuits, motor driven accessories, diagnosing motor driven accessories, Electronic stability program (ESP), Adaptive cruise control (ACC), Occupant-protection systems, Safe working practices-work cloths, eye protection, fire protection, battery safety.

Starting and charging systems: starting circuits, solenoid shift starters, diagnosing and servicing solenoid shift starters systems, positive engagement starters, diagnosing and servicing positive engagement starting system, gear-reduction starters, diagnosing gear-reduction starters, charging system overview, field circuits, diagnosing and servicing the charging system.

Ignition systems and accessories: Primary and Secondary ignition systems, diagnosing and servicing distributed primary and secondary ignition systems, diagnosing and servicing the secondary ignition system on a distributor-less vehicles, distributor-less ignition primary circuits, diagnosing and servicing the primary circuit on a distributor-less ignition system.

Electronic control units and sensors: Vehicle sensors-speed, Hall phase sensors, temperature sensor, fuel level, battery condition, emissions, feedback circuits, Micromechanical yaw-rate sensors, Accelerator-pedal sensors, Position sensors for transmission control Steering-angle sensors, Axle sensors.

Cooling of Electronics Equipment: Cooling load of electronics equipment, thermal environment, Electronics cooling in automotive systems, air cooling, liquid cooling, immersion cooling.

Learning Resources:

Text Books:

1. Automotive Technology, Electricity and Electronics, Al Santini, Cengage Publishers, 2nd Edition, 2011.
2. Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive, Robert Bosch GmbH, 5th edition, John Wiley & Sons. Inc. and Bentley Publishers, 2007

Reference Books:

1. Understanding Automotive Electronics, William Ribbens, 6th Edition, Elsevier, 2011.

Online Resources:

1. https://www.elprocus.com/

Course Code: ME5552	VEHICLE DYNAMICS	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand the principles underlying the development and design of road vehicles under the influence of dynamic loads.
CO2	Analyze the performance and establish the design specifications for the acceleration and braking conditions.
CO3	Model, simulate and analyze the conventional road vehicles for better ride comfort.
CO4	Analyze the cornering forces and effects of tractive forces on cornering
CO5	Design suspension systems for better damping and comfort

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2	2	2	1
CO2	2	2	3	2	3	2
CO3	2		3	3	2	2
CO4	2	2	3	3	3	2
CO5	3		3	3	3	2

Syllabus:

Introduction: - Hypothetical vehicle control loop, Fundamental Approach, Vehicle coordinates, motion variables. Forces – Dynamic axle loads, Static loads on level ground, aerodynamic forces on body, hitch forces, tire construction, size and load rating, terminology, mechanics of force generation, Tyre wear, tire life, factors affecting tire life – problems

Road Loads: - Aerodynamic, Mechanics of pressure distribution – Aerodynamic forces: lift & drag, Spoilers, Lift force, side force and roll, pitch and yaw moments, Crosswind sensitivity. Rolling Resistance, Factors affecting pressure, velocity, slip temperature, etc – Total road loads – Fuel Economy Effects.

Acceleration & Braking Performance: – Power limited, Traction limited acceleration, Static loads on level ground, aerodynamic forces on body, Fundamental Expressions, Constant retardation, Wind Resistance, Power, Braking forces, Brakes: disc and drum, front, rear and four-wheel braking, Braking Torque, Road friction rolling resistance, problems.

Vehicle Vibration and Ride characteristics: - Excitation sources – road roughness, wheel assembly, driveline excitation, engine transmission. Wheel Hop Resonance. Rigid body bounce, pitch motion. Effect of vibration on vehicle riding. Influence of pressure in tyre, alignment toe in and toe out, tire wear and tyre life.

Suspension: - Solid axes – Independent suspension, Anti-squat and anti- pitch suspension geometry, roll center analysis, Active suspension, suspension load – vehicle loading, load due to gyroscopic force on suspension, total load on suspension.

Steady–State Cornering: - Introduction, Low and high speed turning –Tyre cornering forces, governing expressions, under steer gradient, over steer and neutral conditions. Characteristic speed, critical speed, yaw velocity gain, sideslip angle, static margin. Suspension effects on cornering.

Learning Resources:

Text Books:

1. Tire and Vehicle Dynamics, Hans B Pacejka, 3rd Edition, Elsevier Ltd., 2012.
2. An Introduction to Modern Vehicle Design, J H Smith, Butterworth Heinemann, Oxford, 2010.

Reference Books:

1. Road Vehicle Dynamics, Rao V Dukkipati, Springer 2008
2. Ground Vehicle Dynamics, Werner and Karl, Springer Berlin Heidelberg, 2008.
3. Theory of Ground Vehicles, Wong H, McGraw Hill, Second edition, 2006.
4. Fundaments of Vehicle Dynamics, Thomas D Gillespie, SAE Inc, 2002

Course Code: ME5553	AUTOMOTIVE SYSTEMS LABORATORY	Credits 0-1-2: 2

Prerequisites: I C Engines Lab

Course Outcomes:

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

CO1	Illustrate the functioning of power steering, braking and transmission systems
CO2	Perform tests on chassis dynamometer
CO3	Perform tests on wheel alignment and onboard diagnostic
CO4	Evaluate the performance characteristics of solar and fuel cell systems

Course Articulation Matrix:

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

Syllabus:

S. No	Name of the Experiment
1	Assemble and Dismantle the Old vehicle to study the parts.
2	Study of Power steering system, Braking System, Gear Box and Clutch assembly
3	Wheel alignment test
4	Onboard diagnostic test
5	Vehicle performance test using chassis dynamometer
6	Vehicle emission measurement using chassis dynamometer as per Indian Driving Cycle (IDC)
7	Fuel consumption test
8	V-I characteristics of solar simulator in different configurations
9	Performance test on PEM fuel cell
10	V-I characteristics of solar PV Module in series and parallel configurations
11	Performance test on DMFC fuel cell
12	Study of vehicle lighting system and Bendix drive

Learning Resources:

Text Books:

1. Automobile Engineering, By K.M.Gupta.l, Vol.I & II, Umesh Pub, 2010
2. PEM Fuel Cells-Theory and Practice, Frano Barbir, Elsevier Academic Press-2005.
3. Electric vehicle technology explained, James Larmine, John Wiley and Sons, 2013.

Course Code: ME5554	ENGINEERING ANALYSIS AND SIMULATION LABORATORY	Credits 0-1-2: 2

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand the role of CAE and CFD on development for automotive systems
CO2	Solve static structural problems for automotive components.
CO3	Analyze the temperature distribution for heat sink and IC Engine cylinder head
CO4	Solve vehicle aerodynamics and perform combustion analysis using CFD Package

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	1
CO2	2	3	3	3	2	1
CO3	2	3	3	3	3	1
CO4	2	3	3	3	3	1

Syllabus:

Finite Element analysis of automotive Structures

1. Import CAD geometry to the CAE and CFD Packages
2. Static Structural Simulation of Automotive Chassis frame
3. Static Thermal analysis of Heat Sink
4. Static Thermal analysis of IC Engine Cylinder head
5. Explicit dynamics Simulation for Crashworthiness of Vehicle body
6. Random vibration analysis of suspension system

Computational Fluid Dynamics analysis of automotive Systems

1. CFD analysis of Lid-driven Cavity
2. CFD analysis of Ahmed Body
3. Assessment of Turbulence models for Ahmed Body
4. CFD analysis of vehicle aerodynamics and methods to reduce drag of vehicle
5. CFD analysis of a heat exchanger
6. CFD analysis of Combustion in Engines

Learning Resources:

Text Books:

1. An introduction to computational fluid dynamics: the finite volume method, H.K. Versteeg, W. Malalasekera, Pearson, 2008, 2nd edition
2. Introduction to Finite Elements in Engineering, Tirupathi R. Chandrupatla, Ashok D. Belegundu, Prentice Hall (2002)

Online Resources:

1. A Hands-on Introduction to Engineering Simulations by Dr. Rajesh Bhaskaran (Cornell University), EdX Course (Link: https://learning.edx.org/course/course-v1:CornellX+ENGR2000X+1T2018/home)

Course Code: ME5598	SEMINAR-II	Credits 0-0-3: 1

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify and compare technical and practical issues related to the area of course specialization.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of technical writing and critical thinking
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	1	2
CO2	3	3	2	2	2	3
CO3	3	3	2	2	2	2
CO4	3	2	2	2	2	2

Evaluation Scheme:

Task	Description	Weightage
I	Clarity on the topic	10
II	Literature survey	30
III	Content	30
IV	Presentation	20
V	Response to Questions	10
TOTAL		**100**

Task CO-PO mapping:

Task/CO	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

II-YEAR I-SEMESTER

Course Code: ME6547	COMPREHENSIVE VIVA – VOCE	Credits 2

Prerequisites: Nil

Course Outcomes:

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

CO1	Comprehend the knowledge gained in the course work
CO2	Infer principles of working of automotive systems.
CO3	Acquaint with automobile technology and improve the ability in problem solving.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	2	3	2
CO2	2	1	2	2	3	2
CO3	2	1	3	3	3	2

Course Code: ME6549	DISSERTATION: PART-A	Credits 12

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify a topic in advanced areas of Automobile Engineering through review of literature.
CO2	Identify gaps to formulate objectives & scope of the work.
CO3	Develop research methodology to meet the objectives.
CO4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives
CO5	Solve the problem and analyze the results obtained

Course Articulation Matrix:

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

M.Tech Dissertation Rubric Analysis:

I	Selection of Topic
II	Literature Survey
III	Defining the Objectives and Solution Methodology
IV	Performance of the Task
V	Dissertation Preparation
VI	Review (Presentation & Understanding)
VII	Viva-Voce
VIII	Publications /Possibility of publication

Task **(% Weightage)**	CO1	CO2	CO3	CO4
I (10)	X			
II (20)		X		
III (30)			X	
IV (40)				X

II-YEAR II-SEMESTER

Course Code: ME6599	DISSERTATION: PART - B	Credits 20

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify methods and materials to carry out experiments/develop code.
CO2	Reorganize the procedures with a concern for society, environment and ethics.
CO3	Analyze and discuss the results to draw valid conclusions.
CO4	Prepare a report as per the recommended format and defend the work.
CO5	Explore the possibility of publishing papers in peer reviewed journals/conference Proceedings.

Course Articulation Matrix:

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

M.Tech Dissertation Rubric Analysis:

I	Selection of Topic
II	Literature Survey
III	Defining the Objectives and Solution Methodology
IV	Performance of the Task
V	Dissertation Preparation
VI	Review (Presentation & Understanding)
VII	Viva-Voce
VIII	Publications /Possibility of publication

	ME 5599				
Task (% Weightage)	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
IV (40)	X	X			
V (20)				X	
VI (10)			X		
VII (20)				X	
VIII (10)					X

DETAILED SYLLABUS
ELECTIVE COURSES
(I – YEAR, I – SEMESTER)

Programme Specific Professional Elective Courses

Course Code: ME5511	NOISE, VIBRATIONS & HARSHNESS	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify sources of noise and vibration
CO2	Measure sound intensity and human sensitivity
CO3	Model statistical energy analysis and simulators
CO4	Evaluate active control techniques
CO5	Evaluate the signal processing techniques.

Course Articulation Matrix:

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

Syllabus:

NVH in the Automotive Industry: Sources of noise and vibration. Design features. Common problems. Marque values. Noise quality. Pass-by noise requirements. Target vehicles and objective targets. Development stages in a new vehicle programme and the altering role of NVH engineers.

Sound and Vibration Theory: Sound measurement. Human sensitivity and weighting factors. Combining sound sources. Acoustical resonances. Properties of acoustic materials. Transient and steady state response of one degree of freedom system applied to vehicle systems. Transmissibility. Modes of vibration.

Test Facilities and Instrumentation: Laboratory simulation: rolling roads (dynamometers), road simulators, semi-anechoic rooms, wind tunnels, etc. Transducers, signal conditioning and recording systems. Binaural head recordings., Sound Intensity technique, Acoustic Holography, Statistical Energy Analysis.

Signal Processing: Sampling, aliasing and resolution. Statistical analysis. Frequency analysis. Campbell's plots, cascade diagrams, coherence and correlation functions.

NVH Control Strategies & Comfort: Source ranking. Noise path analysis. Modal analysis. Design of Experiments, Optimisation of dynamic characteristics. Vibration absorbers and Helmholtz resonators. Active control techniques.

Learning Resources:

Text Books:

1. Fundamental of Noise and Vibration, Norton M P, Cambridge University Press,2001
2. Acoustic Ducts and Mufflers, Munjal M.L., John Wiley, 2002

Reference Books:

1. Noise Control of Internal Combustion Engine, Baxa, John Wiley, 2000.
2. Model Testing : Theory and Practice, Ewins D. J., John Wiley,1995.
3. Dynamic Vibration Absorbers, Boris and Kornev, John Wiley, 1993.
4. Vibration Testing Theory and Practice, McConnell K, John Wiley, 1995.

Course Code: ME5512	THERMO-FLUID ENGINEERING FOR AUTOMOBILES	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand the principles and applications of thermofluids in automotive systems.
CO2	Identify the drag reduction techniques for better aerodynamic performance of automobiles.
CO3	Apply principles of heat transfer to develop mathematical models for multi-mode heat transfer problems.
CO4	Apply the concepts of thermofluids for design of heat exchangers in automotive systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	2	1
CO2	2	2	3	3	3	1
CO3	2	2	3	3	3	1
CO4	2	2	3	3	3	1

Syllabus:

Introduction: Essentials of thermofluidics in automotive systems, Basic Definition of Thermofluids, a brief review on energy sources and conversion, a discussion on various power producing devices in the automotive industry.

Vehicle Aerodynamics: Lagrangian and Eulerian description, Reynolds transport theorem, Incompressible viscous flow, derivation of conservation equations of mass and momentum for both laminar and turbulent flow, Exact solutions of Navier-Stokes Equations, Boundary layer theory, external aerodynamics over bluff bodies, methods to reduce drag, Impact of aerodynamics on vehicle shape, incompressible viscous flow through ducts, a brief discussion on compressible flow and automotive aero-acoustics.

Automotive Thermal Management: Classification of modes of heat transfer, The Heat Conduction Equation, Analytical Solution of Heat Conduction Equation, Transient Heat Conduction, Natural and Forced Convection (Boundary layer analogies, Internal and external flows and Analytical Solutions), Fundamental principles of Thermal Radiation, Radiation exchange between surfaces - View factor, Radiation shields, Multimode heat transfer, Engine Cooling, Thermal Management of Hybrid Electrical Vehicles, Automotive Air-Conditioning and comfort control

Two-Phase Flow: Fundamentals of Phase-Change Process, Pool Boiling and Flow Boiling, Film condensation and dropwise condensation: Analytical Solutions and Empirical Correlations.

Applications of Thermofluids in Automotive engineering: Heat Exchanger in automotive industry, Types of heat exchangers, Analysis of Shell and Tube Heat Exchanger, Transient Analysis of Concentric Heat Exchangers etc.

Learning Resources:

Text Books:

1. Engineering Thermofluids, Mahmoud Massoud, Springer 2015
2. Fundamentals of heat and mass transfer, Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt, 8th Edition, Wiley
3. Introduction to Fluid Mechanics, Fox, R.W., Pritchard, P. J. and McDonald, A. T., 8th Edition, Wiley, 2018.

Reference Books:

1. Automotive Aerodynamics, Joseph Katz, Wiley, 2016
2. Process Heat Transfer, Donald Q. Kern, McGraw – Hill, New York

Online Resources:

1. Advanced Fluid Mechanics, Dr. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105218/#)
2. Heat and Mass Transfer, Prof. U.N. Gaitonde and Prof. S.P. Sukhatme (IIT Bombay), NPTEL Course (Link: https://nptel.ac.in/courses/112/101/112101097/#)

Course Code ME5513	ALTERNATE FUELS AND EMISSIONS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand the need of alternate fuels for IC engines
CO2	Evaluate the performance of the engine with alternate fuels and blends with petroleum derived fuels.
CO3	Examine the viable production and storage methods of alternate fuels.
CO4	Measure the pollutant emissions from IC Engines as per standards and describe emission control methods.

Course Articulation Matrix:

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

Syllabus:

Introduction: Present energy scenario (worldwide and India)- Statistics of petroleum fuels- of liquid and gaseous fuels in Automobiles-Problems with highly exploited petroleum derived fuels-Desirable properties of a good alternate fuel – Availability and properties of alternate fuels, ASTM standards.

Alcohols: General Use of Alcohols – Thermo-combustion properties as Engine fuel – Gasolene and alcohol blends – Production methods of widely used alcohols-Performance in SI and CI Engines – Methanol and ethanol and Gasolene/diesel blends – Combustion Characteristics in engine – emission characteristics-Modification required to operate with alcohols and its blends with petrol and diesel-brief details of flexi fuel engines(FFE)-use of higher alcohols.

Natural Gas, LPG: Use of natural gas as CNG and LNG-Availability of CNG and LNG-, properties, modification required to use in engines – performance and emission characteristics of CNG using LPG in SI & CI engines.-Production and storage of CNG/LNG.

Bio-gas: Production methods of bio-gas, properties of bio-gas as a fuel, performance and emission characteristics of engine with bio-gas and its blends with petrol/diesel-brief information on compressed gio-gas and its storage.

Vegetable oils: Characteristics of vegetable oils as alternate fuel- edible and non-edible vegetable oils-conversion of vegetable oils into diesel like fuel(biodiesel) -esterification, blending and micro-emulsions-Performance and emission characteristics of engines with biodiesel and blends-B20.

Hydrogen : Suitable characteristics of hydrogen fuel- hydrogen production methods- storage of hydrogen-use of hydrogen as fuel in engines -Hydrogen in fuel cells.

Engine Emissions : Harmful effects of engine-out emissions-Mechanism of formation of pollutant emissions such as carbon monoxide, unburned hydrocarbons, oxides of hydrogen and aldehydes.

Emission measurement and control methods: Measurement of pollutants using flame ionization detection, NDIR, chemiluminescent analyzer and particulate matter(soot/smoke)-Emission norms-EURO and Bharat stage Engine emission control methods-in cylinder and after treatment methods.

Learning Resources:

Text Books:

1. Alternative Transportation Fuels: Utilisation in Combustion Engines, M.K. Gajendra Babu , K.A. Subramanian CRC Press ,2013
2. Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines,Akhilendra Pratap Singh, Yogesh C. Sharma,Nirendra N. Mustafi ,Avinash Kumar Agarwal, Springer 2020.

Reference Books:

1. Engine Emissions: Pollutant formation and advances in control Technology, Norbe Pundir B.P, Narosa Publishing House,2013.
2. Alternative Fuels for Transportation, Ramadhas, A S,CRC Press 2012.

Online Resources:

1. https://nptel.ac.in/courses/112/104/112104033/Engine Emissions-B.P.Pundir

Course Code: ME5514	ENGINE MANAGEMENT SYSTEMS	Credits 3-0-0: 3

Prerequisites: I C Engines

Course Outcomes:

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

CO1	Identify the modern automobile accessories and engine management systems.
CO2	Understand the computerized engine testing and diagnosis procedures for manufactures of engine control systems.
CO3	Understand the concept of various sensors and actuators
CO4	Classify SI and CI engine management systems
CO5	Understand the principles and application of electronic fuel and ignition management systems in the modern automobile.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3		2	
CO2	3		2		2	
CO3	3	2	3	1	3	2
CO4	2		3		3	
CO5	3	2	3	1	2	

Syllabus:

Engine Input Sensors: Coolant & Intake Temperature, Crankshaft Position, Camshaft Position, Manifold Absolute Pressure, Throttle Position, Oxygen, Air/Fuel Ratio, Knock Speed & Distance, Battery & Switches

Output Devices: Relays, Injector Sequencing & Management, Ignition Operation, Idle Air Control, EGR, EVAP, Wastegate Solenoids, Torque Converter & Speed Control, Malfunction Indicator Light

Speed Density/Mass Air Flow Fuel Management Strategies: Key ON Mode, Crank Mode, Open & Closed Loop, Wide-Open Throttle, Adaptive Memory Cells, Cruise &Deceleration, Wide-Open Throttle, Key OFF Mode

Fuel Injection Systems: Electronic Fuel Systems, Computer Self-Diagnostic Circuits, Electronic Throttle Actuator Control Systems, Fuel Control, Fuel Supply System Control, Injection System Inspection and Maintenance.

Engine Diagnostic Procedures: Fuel System testing, On Board Diagnostics, Monitored & Non Monitored Circuits, Diagnostic Trouble Codes.

Digital Engine Control System: Open loop and close loop control system, engine cooling and warm up control, idle speed control, acceleration and full load enrichment, deceleration fuel cutoff. Fuel control maps, open loop control of fuel injection and closed loop lambda control exhaust emission control, on-board diagnostics, diagnostics, future automotive electronic systems, Electronic dash board instruments – Onboard diagnosis system.

SI Engine Management: Feedback carburetor system, throttle body injection and multi point fuel injection system, injection system controls, advantage of electronic ignition systems, three way catalytic converter, conversion efficiency versus lambda. Layout and working of SI engine management systems like Bosch Monojetronic, L-Jetronic and LH-Jetronic. Group and sequential injection techniques. Working of the fuel system components. Advantages of electronic ignition systems. Types of solid state ignition systems and their principle of operation, Contactless electronic ignition system, Electronic spark timing control.

CI Engine Management: Fuel injection system, parameters affecting combustion, noise and emissions in CI engines. Pilot, main, advanced, post injection and retarded post injection. Electronically controlled Unit Injection system. Layout of the common rail fuel injection system. Working of components like fuel injector, fuel pump, rail pressure limiter, flow limiter, EGR valve control in electronically controlled systems.

Learning Resources:

Text Books:

1. Halderman, J. & Linder, J. (2012). Automotive Fuel and Emissions Control Systems (3rd Edition)Upper Saddle River, NJ: Pearson Education.
2. Halderman, J. D. (2011). Diagnosis &Troubleshooting of Automotive Electrical, Electronic, &Computer Systems (6th Edition) Upper Saddle River, NJ: Pearson Education.
3. Diesel Engine Management by Robert Bosch, SAE Publications, 3rd Edition, 2004
4. Gasoline Engine Management by Robert Bosch, SAE Publications, 2nd Edition, 2004
5. Understanding Automotive Electronics – Bechfold SAE 1998
6. Automobile Electronics by Eric Chowanietz SAE.
7. Fundamentals of Automotive Electronics - V.A.W.Hilliers - Hatchin, London

Reference Books:

1. Automobile Electrical & Electronic Equipments (2000) Young, Griffitns - Butterworths, London.
2. Understanding Automotive Electronics, Wiliam B. Ribbens, 5th Edition, Newnes, Butterworth–Heinemann, 2001.
3. Automotive Computers & Digital Instrumentation – Robert N. Brandy, Prentice Hall, 2004
4. The Fundamentals of Electrical Systems - John Hartly - Longman Scientific & Technical, 2002.

Department Elective Courses Offered by Thermal Engineering Section

Course Code: ME5113	RENEWABLE SOURCES OF ENERGY	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Identify the renewable energy sources, their utilization and storage
CO2	Understand the basic concepts of the solar radiation and analyze the solar thermal systems for their utilization
CO3	Understand the principle of working of solar cells and their modern manufacturing techniques
CO4	Analyze wind energy, biomass and Fuel cell systems and their applications
CO5	Design of solar thermal and energy storage systems for specific applications
CO6	Evaluate the energy conversion from ocean thermal energy, geothermal energy, biomass and magneto hydrodynamic power generation

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	3	3
CO2	3	2	2	3	3	2
CO3	2	2	3	3	3	2
CO4	2	2	2	1	3	2
CO5	3	3	3	2	3	2
CO6	2	2	2	1	3	2

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns. Classification of energy resources, Environmental Aspects of Energy – Global warming & Climate change – Role of Renewables, Energy-Environment-Economy, energy scenario in the world and India, Thermodynamics of Energy Sources – A brief review.

Energy storage: Necessity for energy storage. Classification of methods of energy storage. Thermal energy storage; sensible heat storage, latent heat storage., Mechanical energy storage: Pumped hydel storage, Compressed air storage and Flywheel storage, Reversible chemical reaction storage. Electromagnetic energy storage. Hydrogen energy storage. Chemical battery storage.

Basic sun-earth relationships: Definitions. Celestial sphere, altitude-azimuth, declination-hour angle and declination-right ascension coordinate systems for finding the position of the sun, celestial triangle and coordinates of the sun. Greenwich Mean Time, Indian Standard Time, Local Solar Time, sunrise and sunset times & day length.

Solar radiation: Nature of solar radiation, solar radiation spectrum, solar constant, extra-terrestrial radiation on a horizontal surface, attenuation of solar radiation, beam, diffuse and global radiation. Measurement of global, diffuse and beam radiation. Prediction of solar

radiation; Angstrom model, Page model, Hottel's model, Liu and Jordan model etc. Insolation on an inclined surface, angle of incidence.

Solar thermal systems: Principle of working of solar water heating systems, solar cookers, solar desalination systems, solar ponds, solar chimney power plant, central power tower power plants etc. Classification of solar concentrators, Basic definitions such as concentration ratio, angle of acceptance etc., Tracking of the sun; description of different tracking modes of solar collectors and the determination of angle of incidence of insolation in different tracking modes , Concept of Green building and associated design parameters.

Photovoltaic energy conversion: Introduction. Single crystal silicon solar cell, i-v characteristics, effect of insolation and temperature on the performance of silicon cells. Different types of solar cells. Modern technological methods of producing these cells. Indian and world photovoltaic energy scenario. Solar Cell, Module, and Array Construction, Maximizing the Solar PV Output and Load Matching.

Wind energy: Origin of winds, nature of winds, wind data measurement, Variation of Wind Speed with Height, Basics of fluid mechanics, Estimation of Wind Energy at a Site: Betz's law, Wind Turbine Aerodynamics, wind turbine types and their construction, wind-diesel hybrid system, environmental aspects, Wind Energy Storage, wind energy programme in India and the world.

Fuel cells: Introduction, applications, classification, different types of fuel cells such as phosphoric acid fuel cell, alkaline fuel cell, PEM fuel cell, MC fuel cell. Thermodynamic analysis of fuel cells, Development and performance fuel cells.

Biomass: Introduction, photosynthesis, biofuels, biomass resources, biomass conversion technologies, urban waste to energy conversion, biomass to ethanol conversion, biomass energy scenario in India, biogas production, constant pressure and constant volume biogas plants, operational parameters of the biogas plant, design of bio-digester, Energy Farming

Other forms of Energy: Ocean energy : Ocean thermal energy; open cycle & closed cycle OTEC plants, environmental impacts, challenges, present status of OTEC systems. Ocean tidal energy; single basin and double basin plants, their relative merits. Ocean wave energy; basics of ocean waves, different wave energy conversion devices, relative merits; **Geothermal energy:** Origin, applications, types of geothermal resources, relative merits; **Magneto hydrodynamic Power Generation:** applications; Origin and their types; Working principles.

Learning Resources:

Text Books:

1. Non conventional Energy Resources, B.H.Khan, Tata McGraw Hill, New Delhi, 2017, 3rd edition
2. Energy Technology: Non-Conventional, Renewable and Conventional, S.Rao and B.B.Parulekar, Khanna Publishers, 2010, 1st Edition.

Reference Books:

1. Solar Energy-Principles of Thermal Collection and Storage, S.P.Sukhatme and J.K.Nayak, TMH, 2010, 3rd edition (6 reprint).
2. Solar Energy Thermal Processes, J.A.Duffie and W.A.Beckman, John Wiley, 2013, 4th edition.

Online Resources:

1. Non-conventional Energy Resources by Prof. Prathap Haridoss (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/121/106/121106014/)

Course Code: ME5114	ENERGY SYSTEMS AND MANAGEMENT	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand the fundamentals of energy management
CO2	Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.
CO3	Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.
CO4	Design viable energy projects.

Course Articulation Matrix:

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

Syllabus:

Introduction: Review of the concepts of Thermodynamics, Fluid Mechanics and Heat Transfer, Need for energy storage, Grid balancing: Supply and demand concept for energy management. Heat transfer equipment- Heat exchangers, Steam plant

Energy storage Methods and systems: Thermal, Electrical and Mechanical energy storage methods and systems, Energy saving in IC engines and Gas turbines.

Direct Energy Conversion methods: Magneto-hydrodynamic (MHO) power generation, Thermionic power generation, Thermoelectric power generation, Fuel cells, Hydrogen energy system

Heat recovery systems: Incinerators, regenerators and boilers

Energy Conservation: Methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems

Energy Management: Principles of Energy Management, Energy demand estimation, Organising and Managing Energy Management Programmes, Energy pricing

Energy Audit: Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries, Economic Analysis: Scope, Characterization of an Investment Project and Case studies.

Learning Resources:

Text Books:

1. Energy Management audit & Conservation, De, B. K., Vrinda Publication, 2010, 2nd Edition.

2. Energy Management, Murphy, W. R., Elsevier, 2007, 1st Edition.

Reference Books:

1. Energy Management Hand book, Doty, S. and Truner, W. C., Fairmont Press, 2009, 7th edition.

Online Resources:

1. International Energy Agency Website, (Link: https://www.iea.org/)
2. Indian Renewable Energy Development Agency Limited Website, (Link: https://www.ireda.in)
3. Ministry of Power, GoI, Website, (Link: https://powermin.gov.in/)

Department Elective Courses Offered by Materials and Systems Engineering Design

Course Code: ME5613	MECHANICS OF METAL FORMING	Credits 3-0-0: 3

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Understand the practical applications of metal forming.
CO2	Solve for strain rates, temperatures and metallurgical states in forming problems.
CO3	Develop process maps for metal forming processes using plasticity principles.
CO4	Estimate formability limits for sheets and bulk metals and workability of different ductile materials.
CO5	Apply FE principles to simulate metal forming processes.

Course Articulation Matrix:

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

Syllabus:

Introduction: Metal forming as a manufacturing process and its relation with other processes – Classification based on type of stresses - Examples.

Description of Material properties: Tensile test, effect of properties on forming. Sheet deformation processes: Uni-axial tension, general sheet forming processes, Yield criteria, Flow rule, Yield criterion and flow rule for Anisotropic material, work of plastic deformation, isotropic and anisotropic yield functions, Bauschinger effect modelling, effective stress and strain. Sheet deformation in plane stress: strain distributions, strain diagram, deformation modes, effective stress-strain laws, principal tensions.

Rolling Processes: Analysis of longitudinal strip or sheet rolling process (calculation of roll separating force, torque & power, angle of bite, maximum reduction in rolling), rolling defects.

Forging processes: Metal flow in forging, Analysis of plane strain compression, Analysis of compression of circular disc.

Extrusion Processes: Calculation of extrusion load, advances in extrusion, Defects in extrusion. Direct & indirect extrusion.

Wire Drawing Processes: Introduction, wire drawing load calculation.

Sheet forming: Mechanics: Flow Rules – Anisotropy - Formability of sheet, Formability tests, forming limit diagrams, strain path diagrams, Case studies.

Pressing and Sintering: Workability Studies – Densification

Recent advances: Hydroforming, tailor welded blanks, friction stir welding of sheets, incremental sheet forming.

Modelling and Simulation in Metal Forming: The Plane Strain Compression Test, FEM Model and Input Data to the Model - process simulation for deep drawing, Effective Strain and Strain-Rate, Distributions in Deformed Zones.

Case studies: Case studies on the manufacturing aspects of products using the lessons learnt.

Learning Resources:

Text Books:

1. Sheet metal forming processes Constitutive modelling and numerical simulation, D. Banabic, Springer-Verlag Berlin Heidelberg, 2010
2. Mechanics of sheet metal forming, Butterworth-Heinemann, Z. Marciniak, J. L. Duncan, S. J. Hu, Elsevier, 2002
3. Fundamentals of metal forming, R. H. Wagoner, J. L. Chenot, John Wiley and Sons, 1997
4. Metal forming Mechanics and Metallurgy, W. F. Hosford, R. M. Caddell, Printice Hall, 2007

Reference Books:

1. Modelling Techniques for Metal Forming Processes, G.K. Lal, P.M. Dixit and N.Venkat Reddy, Alpha Science, 2011
2. Theory of Plasticity, J. Chakrabarty, McGraw Hill, 1998.
3. Basic engineering plasticity, D. W. A. Rees, Elsevier, 2000
4. Theory of Engineering Plasticity, R. Narayanasamy, R Ponalagusamy, Ahuja Book Company, 2000.
5. Applied Metal Forming - Including FEM Analysis, Henry S. Valberg, Cambridge University Press, 2010.

Department Elective Courses Offered by Computer Integrated Manufacturing Section

Course Code: ME5311	ENTERPRISE RESOURCE PLANNING	Credits 3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Understand the concepts of ERP and managing risks.
CO2	Choose the technologies needed for ERP implementation.
CO3	Develop the implementation process.
CO4	Analyze the role of Consultants, Vendors and Employees.
CO5	Evaluate the role of PLM, SCM and CRM in ERP.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	2	2	1
CO2	2	1	2	2	3	2
CO3	2	2	2	2	2	1
CO4	2	1	2		1	1
CO5	2	1	2	2	2	1

Syllabus:

Introduction to ERP: Enterprise – an overview, brief history of ERP, common ERP myths, Role of CIO, Basic concepts of ERP, Risk factors of ERP implementation, Operation and Maintenance issues, Managing risk on ERP projects.

ERP and Related Technologies: BPR, Data Warehousing, Data Mining, OLAP, PLM, SCM, CRM, GIS, Intranets, Extranets, Middleware, Computer Security, Functional Modules of ERP Software, Integration of ERP, SCM and CRM applications.

ERP Implementation: Why ERP, ERP Implementation Life Cycle, ERP Package Selection, ERP Transition Strategies, ERP Implementation Process, ERP Project Teams.

ERP Operation and Maintenance: Role of Consultants, Vendors and Employees, Successes and Failure factors of ERP implementation, Maximizing the ERP system, ERP and e-Business, Future Directions and Trends.

Learning Resources:

Text Books:

1. Enterprise Resource Planning, Alexis Leon, Tata McGraw Hill, Second Edition, 2008.

2. ERP in Practice, Jagan Nathan Vaman, Tata McGraw Hill, 2007.

3. ERP: Tools, Techniques, and Applications for Integrating the Supply Chain, Carol A Ptak, CRC Press, 2003, 2nd Edition.

Course Code: ME5312	MANUFACTURING MANAGEMENT	Credits 3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Design of production planning and control systems encompassing competitive priorities and strategies.
CO2	Evaluate and interpret Demand Forecast for production planning.
CO3	Design an optimal facility layout and select appropriate product design approach.
CO4	Apply ROP, MRP and JIT systems for inventory control in production systems by considering SCM issues.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	3	2
CO2	2		1	2	1	
CO3	3	2	2	2	2	1
CO4	2	1	2	3	3	1

Syllabus:

Competitive priorities and manufacturing strategy: Introduction, Historical perspective of manufacturing management, Competitive priorities and operational strategy, Functional area strategy and Capability, Case Study.

Demand Forecasting: Introduction, Quantitative Methods introduction, Time series and moving averages method, Exponential Smoothing method, Regression Analysis Method, Qualitative Methods.

Facility Design: Introduction and History, Product design and process selection, Capacity planning, Plant location and Plant layout.

Inventory control: From EOQ to ROP, Independent Demand Inventory control & Economic Order Quantity (EOQ), Dynamic lot sizing, Statistical inventory control models.

The MRP crusade: History, Need, Evolution, Dependent Demand & Material Requirement Planning (MRP), Structure of MRP system, MRP Calculations.

The JIT revolution: Just-in-Time System: origin & goals, Characteristics of JIT Systems, Continuous Improvement, The Kanban System, Strategic Implications of JIT System.

Production Planning and Control: Shop floor control, Production scheduling, Aggregate planning, Aggregate and workforce planning.

Supply Chain Management: Introduction to Supply Chain Management, Decision phases in a supply chain, Process views of a supply chain: push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope.

Text Books:

1. Operations Management: Strategy and Analysis, Krajewski U and Ritzman LP, Pearson Education Pvt Ltd., Singapore, 2002.
2. Operations Management, Gaither N and Frazier G, Pearson, 12th Edition, 2001.

Reference Books:

1. Operations Management for Competitive Advantage, Chase RB, Aquilano NJ and Jacobs RF, McGraw-Hill Book Company, NY, 2001.

Course Code: ME5313	SOFT COMPUTING TECHNIQUES	Credits 3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Classify and differentiate problem solving methods and tools.
CO2	Apply A*, AO*, Branch and Bound search techniques for problem solving.
CO3	Formulate an optimization problem to solve using evolutionary computing methods.
CO4	Design and implement GA, PSO and ACO algorithms for optimization problems in Mechanical Engineering.
CO5	Apply soft computing techniques for design, control and optimization of Manufacturing systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			1			
CO2	2		2	3	1	
CO3	3		2	1	2	
CO4	3		3	3	2	
CO5	3	2	2	3	2	1

Syllabus:

Problem Solving Methods and Tools: Problem Space, Problem solving, State space, Algorithm's performance and complexity, Search Algorithms, Depth first search method, Breadth first search methods their comparison, A*, AO*, Branch and Bound search techniques, p type, Np complete and Np Hard problems.

Evolutionary Computing Methods: Principles of Evolutionary Processes and genetics, A history of Evolutionary computation and introduction to evolutionary algorithms, Genetic algorithms, Evolutionary strategy, Evolutionary programming, Genetic programming.

Genetic Algorithm and Genetic Programming: Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, applications.

Swarm Optimization: Introduction to Swarm intelligence, Ant colony optimization (ACO), Particle swarm optimization (PSO), Artificial Bee colony algorithm (ABC), Other variants of swarm intelligence algorithms.

Advances in Soft Computing Tools: Fuzzy Logic, Theory and applications, Fuzzy Neural networks, Pattern Recognition, Differential Evolution, Data Mining Concepts, Applications of above algorithms in manufacturing engineering problems.

Deep Neural Networks: Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks. Back propagation algorithm, factors affecting back propagation training, applications.

Application of Soft Computing to Mechanical Engineering/Production Engineering Problems: Application to Inventory control, Scheduling problems, Production, Distribution, Routing, Transportation, Assignment problems.

Learning Resources:

Text Books:

1. Soft Computing Integrating Evolutionary, Neural and Fuzzy Systems, Tettamanzi Andrea, Tomassini and Marco, Springer, 2001.
2. Artificial Intelligence, Elaine Rich, McGraw Hill, 2/e, 1990.
3. Multi-objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley and Sons, 2001.
4. Optimization for Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, Ltd, 2012.

References:

1. https://in.mathworks.com/content/dam/mathworks/ebook/gated/machine-learning-ebook-all-chapters.pdf.

Online Resources:

1. https://www.iitk.ac.in/kangal/index.shtml

Department Elective Courses Offered by Machine Design Section

Course Code: ME5404	COMPUTER-AIDED GEOMETRIC DESIGN	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student shall be able to:

CO1	Apply geometric transformations and projection methods in CAD
CO2	Develop geometric models to represent curves
CO3	Design surface and solid models for engineering design
CO4	Apply mesh generation techniques for engineering analysis

Course Articulation Matrix:

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

Syllabus:

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Geometric modelling.

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, Applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections Implementation of the projection formulations using computer codes.

Introduction to Geometric Modeling for Design: Introduction to CAGD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modelling.

Curves in Geometric Modeling for Design: Differential geometry of curves, Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Conversion of one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, Parametric representation, Curvatures, Developable surfaces. Surfaces entities (planar, surfac of revolution, lofted etc). Free-for surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD softwares. Data Exchange Formats and CAD Applications:

Meshing Methods for Engineering Analysis: FEM, Meshing, Quality of meshing, Mesh generation methods.

Learning Resources:

1. Geometric Modeling, Michael E. Mortenson, Tata McGraw Hill, 2013.
2. Computer-Aided Engineering Design, Saxena and B. Sahay, Anamaya Publishers, New Delhi, 2005.
3. An introduction to NURBS: with historical perspective, Rogers, David F.Morgan Kaufmann Publishers, USA, 2001.
4. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, TMH, 2008.
5. Principles of CAD/CAM/CAE systems, Kunwoo Lee, Addison-Wesley (1999).

Course Code: ME 5412	CHARACTERIZATION OF ENGINEERING MATERIALS	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student shall be able to:

CO1	Identify advanced techniques available for characterization of materials
CO2	Select a characterization technique to evaluate the behavior of materials
CO3	Analyze defects and failure surfaces of materials
CO4	Analyze the characterization results by various equipment

Course Articulation Matrix:

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

Syllabus:

Introduction: Overview of the course; materials classification and their properties, Importance of materials selection, property classification, Criteria for selection of materials, Ashby charts for materials selection, Engineering Design process and the role of materials; material property charts; selection of materials based on function, objective, constraints and free variables; examples of material selection for typical applications;

Computer aided materials selection: Selection of process based on material classification; pencil curve approach; material selection for multiple constraints and multiple objective cases; multiple constraints and conflicting objectives. Co-selection of material and shape; concept of macroscopic and microscopic shape factors; Four quadrant method of material selection. General Properties of plastics, polymers and elastomers; visco-elastic properties; short-term and long-term properties of plastics;

High temperature materials: families of super alloys and their characteristics; creep and fatigue resistance of super alloys; role of precipitates in strengthening of super alloys; repair of super alloys after creep damage; coatings for high temperature materials.

Fundamentals of ceramics: general properties, applications of ceramics for critical applications. Design considerations. Surface treatment of materials using coatings; type of coatings; PVD and CVD coatings. Basics of electro-plating and electro-less plating.

Physical characterization of materials: Optical Microscopy, SEM,TEM, Density, Void content in materials, Electron Probe Micro Analyzer (EPMA), Atomic Force Microscopy (AFM), Thermogravimetric analysis (TGA), nano indentation, NMR spectroscopy, EDAX, FTIR, XRD

Mechanical characterization: Tensile test, flexural test, compression test, ILSS, creep, fatigue, Hardness, Impact test, Fracture toughness test, Principle, construction and operation working parameters, equipment operation. selection of plastics based on mechanical properties, degradation due to environment, of laminates.

Tribological characterization: Abrasive wear, Pin-on Disc, Erosion test, Corrosion test, sand abrasion, slurry erosion, scratch test, nano indent scratch test, wear; Design methods for snap fits; case studies. Fundamentals of fiber reinforced plastics; Stress, strain analysis of continuous fiber composites, rule of mixtures, general deformation behavior

Learning Resources:

1. Materials Selection in Mechanical Design, M.F. Ashby, Butterworth Heinemann, 4/e, 2010
2. Materials Characterization-Introduction to Microscopic and Spectroscopic Methods - Yang Leng, John Wiley & Sons (Asia) Pte Ltd, 2008
3. ASM Handbook: Materials Characterization, ASM International, 2008.
4. Experimental Techniques in Physical Metallurgy, V. T. Cherapin and A. K. Mallik, Asia Publishing House, 1967.
5. Mechanical Metallurgy, Dieter,George E. McGraw Hill, 2nd Edition, 2005
6. Plastics Engineering, Crawford, R. J., Butterworth-Heinemann, 3/e, 2002.
7. Super alloys: A technical guide, Donachie, M. J. and Donachie, S. J., ASM International, 2002.

Course Code: ME5413	ANALYSIS AND SYNTHESIS OF MECHANISMS	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student shall be able to:

CO1	Understand basic mechanisms and machines and formulate the design problem.
CO2	Develop analytical equations for relative position, velocity and acceleration of all moving links.
CO3	Analyze Simple and Complex mechanisms.
CO4	Apply the knowledge of Kinematic theories to practical problems of mechanism design and synthesis.
CO5	Design higher pair kinematic linkages for a given application.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	3	2	1
CO2	3	3	3	3	3	3
CO3	2	3	3	3	3	3
CO4	3	3	3	2	2	2
CO5	3	3	3	3	2	2

Syllabus:

Introduction: review of kinematic chains, equivalent chains and their inversions.

Position analysis: position and systems, co-ordinate transformation, rotation, translation and combined motion, algebraic position analysis, loop closure equations, position of any point on a linkage, transmission angles and toggle positions, position based synthesis of planar mechanisms.

Kinematics of rigid bodies: plane motion of a rigid body, graphical velocity and acceleration analysis, instantaneous centers of velocity, centrodes, velocity of rub, analytical solutions for velocity analysis – velocity of any point on a linkage, acceleration of any point on a linkage, coriollis acceleration, analytical solutions for velocity and acceleration analysis, case studies – four-bar pin joined linkage, four link slider-crank.

Analytical linkage synthesis: types of kinematic synthesis – motion and path generation, number synthesis, dimensional synthesis, two position synthesis for rocker output, precision points, comparison of analytical and graphical two positionsynthesis, three position synthesis.

Graphical linkage synthesis: two position synthesis for rocker output, three position synthesis, position synthesis for more than three positions (four and six bar quick return), coupler curves, exact and approximate straight line mechanisms.

Cam: terminology, types of follower, follower motions, cams, svaj diagrams, law of cam design, single and double dwell cam design using shm, cycloidal displacement, combined functions,

critical path motion, practical design considerations.

Gears and gear trains: law of gearing, involute tooth form, pressure angle, backlash, contact ratio, interference and method to avoid interference, gear trainand its analysis.

Learning Resources:

1. Kinematics Analysis and Synthesis of Mechanisms, A K Mallik, Amitabha Ghosh and Guntur, D CRC Press, 2011
2. Planar Multibody Dynamics, Parviz E Nikravesh, CRC Press, 2016
3. Design of Machinery An Introduction to the Synthesis and Analysis of Mechanisms and Machines, Robert L Norton, 2nd Edition, McGraw Hill reprint 2011
4. Advanced Mechanism Design: Analysis and Synthesis, Sandor and Erdman, vol II, PHI, New Delhi, 2010
5. Theory of Machines and Mechanisms, Shigley, Pennock and Uicker, 4th Edition, Oxford University Press, 2011

DETAILED SYLLABUS
ELECTIVE COURSES
(I – YEAR, II – SEMESTER)

Programme Specific Professional Elective Courses

Course Code: ME5561	FUEL CELL TECHNOLOGY	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand fuel cell fundamentals
CO2	Analyse the performance of PEM fuel cell system
CO3	Demonstrate the operation of different fuel cells
CO4	Apply the modelling techniques for fuel cell systems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	2	2	1
CO2	2	2	2	3	3	2
CO3	1	2	3	3	3	1
CO4	1	2	3	3	2	1

Syllabus:

Overview of Fuel Cells: Description of fuel cell, brief history, classification, working principle, Fuel cell basic chemistry and thermodynamics of fuel cell and performance.

Fuel Cell Thermodynamics: Thermodynamic Potentials, Heat Potential of a Fuel: Enthalpy of reaction, Reaction Enthalpies, Work Potential of a Fuel: Gibbs Free Energy, Relationship between Gibbs Free Energy and Electrical Work, Computing Reversible Voltages, Reversible Voltage Variation with Temperature, Reversible Voltage Variation with pressure, Reversible Voltage Variation with concentration: Nernst Equation, Fuel Cell Efficiency-Ideal and real fuel cell efficiency.

Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents. **Fuel Cell Modeling:** A Basic Fuel Cell Model, 1-D PEM Fuel Cell Model.

Fuels for Fuel Cells: Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others. hydrogen generation and storage; limitations, recent advances.

Overview of fuel cell types: Phosphoric acid fuel cell (PAFC), Polymer electrolyte membrane fuel cell (PEMFC), Alkaline fuel cell (AFC), Molten carbonate fuel cell (MCFC), Solid-oxide fuel cell (SOFC) and other fuel cells.

PEM Fuel cell components: Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, flow field plate design, Fuel cell operating conditions: pressure, temperature, flow rates, humidity. **Direct methanol fuel cell**, active and passive DMFC, methanol cross over and techniques to reduce, current collectors.

Fuel Cell Vehicles: Basic of fuel cell vehicle, Fuel cell hybrid vehicles, etc.

Main components of solid-oxide fuel cells, Cell stack and designs, Electrode polarization, testing of electrodes, cells and short stacks, Cell, stack and system modelling.
Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal , Using renewable fuels for SOFCs.

Learning Resources:

Text Books:

1. Fuel Cell Fundamentals, Ryan O′Hayre, Suk-Won Cha Whitney Colella, second edition, John Wiley & Sons, 2018.
2. PEM Fuel Cells: Theory and Practice, Franno. Barbir, 2nd Ed. Elsevier/Academic Press, 2013.

Reference Books:

1. Fuel Cells and Their Applications, Karl Kordesch & Gunter Simader, VCH Publishers,2001.
2. Fuel Cell Technology Hand Book, Hoogers G., CRC Press, 2010.

Course Code: ME5562	VEHICLE TESTING AND INSTRUMENTATION	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand conceptual development of zero, first and second order instruments used in automobiles.
CO2	Estimate error and uncertainty with regard to instruments and equipment used in engine and vehicle testing.
CO3	Analyse sensing requirements for measurement of measurands such as load, exhaust emissions, aerodynamic forces etc.
CO4	Apply the standards/codes for testing the engines and vehicles.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	1
CO2	2	2	2	2	3	1
CO3	2	2	3	2	3	1
CO4	2	2	3	2	3	2

Syllabus:

Introduction: Need of vehicle testing (engine testing both for performance and emissions in specific) Requirement of standard instrumentation and equipment, certification and national and international standards-Overview of various intricate systems of a vehicle; Importance of expertise in testing, certification

Basics of measurement techniques: Definitions associated with measurements-Least count, resolution, Precision, Accuracy, Error / Uncertainty analysis- Data collection and handling-Simple numerical problems

Engine Testing: Discussion on typical engine performance characteristics. Definition and importance of engine in a vehicle- Road load equation-Testing under constant speed and variable speed condition. Classification of engine dynamometers- Characteristic curves of various types of dynamometers Advantages and limitations of different types engine dynamometers

Combustion process and combustion analysis: Definition of Combustion, Combustion stoichiometry, Brief Discussion on SI engine combustion and CI engine combustion-Measurement of in-cylinder pressure, temperatures- instrumentation- Analysis of p-theta and heat release rate diagrams

Fuel injection systems: Fuel injection for SI and CI engines, Types of different systems-Electronic injection systems and Electronic Control Units-Testing of injection systems. Sensors and Actuators -Types and principle of operation.

Vehicle Emissions: Pollutant formation mechanisms-Emission measurement on engine and chassis dynamometer-Measurement of regulated and non-regulated pollutants-Description of

emission measuring instrumentation-Continuous Volume Sampling-Dilution tunnel-Description of smoke meters-Emission regulations and legislation- EURO and Bharat Stage norms

Vehicle performance and testing techniques: Schematic layout of typical vehicle-Types of testing for both engine in specific, and whole vehicle body. Description of important components of Vehicle and Engine that require testing. Different types of engines for Vehicles- fossil fuel run engines, hybrid and electric vehicles-Testing procedure for electric vehicles- -Chassis and Rolling road dynamometers-Brief introduction to testing of tires, steering, brakes, wheel alignment- Crash testing fundamentals-Introduction to vehicle Noise, Vibration and Harshness

Vehicle Drag & Aerodynamics of Vehicle: Introduction to drag and aerodynamics; Description drag-terms associated; streamlined and bluff bodies-Definition of Ahmed car-adverse effects of drag; Drag measuring techniques-drag reduction strategies.

Vehicle certification: Need for Vehicle certification and facilities required, Proving Grounds-Importance driving cycles-Indian Driving Cycle, MIDC-procedures, Introduction to other country driving cycle-Japan, EUDC. Vehicle testing and certification related codes-IS and Approved Inspection Station (AIS) codes-Testing Centres (India)- ARAI/ICAT/NATRIP.

Learning Resources:

Text Books:

1. An Introduction to Engine Testing and Development, Richard D. Atkins, SAE International 2009.
2. Mechanical Measurements, S.P. Venkateshan, ANE/Athena Books, 2015,2nd Ed.

Reference Books:

1. Experimental Methods for Engineers J.P. Holman Tata McGraw Hill Co. 2007.
2. Advanced Automotive Fault Diagnosis, Tom Denton, Elsevier Butterworth, Heinemann,2006

Online Resources:

1. www.atesteo.com
2. www.nptel.ac.in
3. https://www.araiindia.com/services/department-and-laboratories/vehicle-evaluation

Course Code: ME5563	AUTOMOTIVE SAFETY AND MAINTENANCE	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Identify different safety systems and its role in automobiles
CO2	Classify active, passive safety systems and components
CO3	Describe the working principles of air-bag, ABS, seat-belt controls, comfort and convenience systems
CO4	Examine vehicle maintenance, trouble shooting and suggest as remedial measures.

Course Articulation Matrix:

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

Syllabus:

Introduction: Design of the vehicle body for safety, energy equation, engine location, deceleration of vehicle inside passenger compartment, deceleration on impact with stationary and movable obstacle, concept of crumble zone, safety sandwich construction.

Safety Concepts: Active safety, driving safety, conditional safety, perceptibility safety, operating safety, passive safety: exterior safety, interior safety, deformation behaviour of vehicle body, speed and acceleration characteristics of passenger compartment on impact.

Active Safety: Cruise control system, Lane departure warning, Tire pressure monitoring system, Electronic braking.

Passive Safety Equipments: Seat belt, regulations, automatic seat belt tightener system, collapsible steering column, tiltable steering wheel, air bags, electronic system for activating air bags, bumper design for safety.

Collision Warning and Avoidance: Collision warning system, causes of rear end collision, frontal object detection, rear vehicle object detection system, object detection system with braking system interactions.

Comfort dnd Convenience System: Steering and mirror adjustment, central locking system, Garage door opening system, tyre pressure control system, rain sensor system, environment information system.

Preventive Maintenance of Engine And Transmission Line: Maintenance of cooling and lubricating systems, engine management service - fault diagnosis- servicing emission controls. Scheduling of maintenance of light duty, heavy duty vehicles

Clutch, transmission, axles: general checks, adjustment and service, fault diagnosis.
Steering, Brake, Suspension, Wheel Maintenance: Inspection, Maintenance and Service of Hydraulic brake, Drum brake, Disc brake, Parking brake. Bleeding of brakes. Inspection, Wheel alignment and balance, removing and fitting of tyres, tyre wear and tyre rotation. Inspection, Maintenance and Service of steering linkage.

Learning Resources:

Text Books:

1. Automotive Handbook, Bosch, 8 th Edition, SAE publication, 2011.
2. Automotive Mechanics, Srinivasan, S, 2nd Edition, Tata McGraw- Hill, 2015
3. An Introduction to Modern Vehicle Design, Jullian Happian-Smith, SAE, 2002

Reference Books:

2. Crashworthiness of Vehicles, Johnson, W., and Mamalis, A.G., MEP, London, 1995
2. Rollover Prevention, Crash Avoidance, Crashworthiness, Ergonomics and Human Factors, SAE Special Publication, November 2003

Course Code: ME5564	HYBRID ELECTRIC VEHICLES	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

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

CO1	Understand the need for hybrid electric vehicles and classify based on configuration
CO2	Identify power sources for hybrid electric vehicles
CO3	Analyse plug-in hybrid systems with different energy storage devices.
CO4	Evaluate the HEV configurations with battery, hybrid and fuel cell electric vehicles

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	3	2
CO2	1	2	3	3	3	2
CO3	1	2	3	3	3	1
CO4	2	1	2	2	2	1

Syllabus:

Introduction: Sustainable Transportation - Population, Energy, and Transportation - Environment - Economic Growth – Emissions regulations and norms- impact of modern drive-trains on energy supplies-New Fuel Economy Requirement Emergence of Electric Vehicles-Basics of the EV - Constituents of an EV -Vehicle and Propulsion Loads.

HEV Fundamentals: Classification- Hybridization of the Automobile-Mild Hybrids, Full Hybrids, Plug-In Hybrids and Electric Vehicles with Range Extender Hybrids- Architectures of HEVs - Series HEVs Parallel HEVs - Series–Parallel HEVs - Complex HEVs - Diesel and other Hybrids - Other Approaches to Vehicle Hybridization Basics of the HEV-Importance of HEV- Constituents of an HEV –Vehicle Model - Vehicle Performance - HEV Powertrain Component Sizing - Series Hybrid Vehicle - Parallel Hybrid Vehicle - Electrically Peaking Hybrid Concept - Gradeability Requirement -Selection of Gear Ratio from ICE to Wheel - Wheel Slip Dynamics.

Plug-In Hybrid Electric Vehicles: Basics of Plug-In Hybrid Electric Vehicle (PHEV) - Constituents of a PHEV - Comparison of HEV and PHEV - Basics of Fuel Cell Vehicles (FCVs) - Constituents of a FCV-Some Issues Related to Fuel Cells-Introduction to PHEVs - PHEVs and EREVs - Blended PHEVs - Electricity for PHEV Use -PHEV Architectures - Equivalent Electric Range of Blended PHEVs - Fuel Economy of PHEVs - Well-to-Wheel Efficiency - PHEV Fuel Economy - Utility Factor - Power Management of PHEVs - Vehicle-to-Grid Technology(V2G) - PHEV Battery Charging - Impact of G2V - The Concept of V2G- Advantages of V2G - Case Studies of V2G.

Electric Machines and Drives in HEVs: Introduction - Induction Motor Drives - Principle of Induction Motors - Equivalent Circuit of Induction Motor - Speed Control of Induction Machine - Variable Frequency, Variable Voltage Control of Induction Motors - Efficiency and Losses of Induction Machine - Permanent Magnet Motor Drives - Basic Configuration

of PM Motors - Basic Principle and Operation of PM Motors - Unsaturated Motor -Saturated Motor.

Electric Energy Sources and Storage Devices: - Introduction - Characterization of Batteries - Battery Capacity - Energy Stored in a Battery - State of Charge in Battery (SOC) and Measurement of SOC - SOC Determination - Direct Measurement - Amp-hr Based Measurement - Some Better Methods - Initialization Process - Depth of Discharge (DOD) of a Battery - Specific Power and Energy Density - Ampere-Hour (Charge and Discharge) Efficiency - Number of Deep Cycles and Battery Life - Some Practical Issues About Batteries and Battery Life- Battery Management Implementation - Comparison of Energy Storage Technologies.

Fundamentals of Regenerative Braking: Braking Energy Consumed in Urban Driving - Braking Energy versus Vehicle Speed - Braking Energy versus Braking Power
Braking Power versus Vehicle Speed - Braking Energy versus Vehicle Deceleration Rate - Braking Energy on Front and Rear Axles - Brake System of EV, HEV, and FCV.

Special Hybrid Vehicles: Brief Introduction of Hydraulic Hybrid Vehicles - Regenerative Braking in HHVs-Off-Road HEVs - Hybrid Excavators - Hybrid Excavator Design Considerations - Diesel HEVs Electric or Hybrid Ships- Locomotives.

Learning Resources:

Text Books:

1. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi, CRC Press, 2018, II Edition.
2. Hybrid Electric Vehicles Principles and Applications with Practical Perspectives, Chris Mi, M. Abul Masrur John Wiley & Sons, Inc.,2018, II Edition.

Reference Books:

1. Electric vehicle technology explained, John Lowry and James Larmine, John Wiley and Sons, 2012.
2. Electric and Hybrid Vehicles: Design Fundamentals, Iqbal Hussein, CRC Press, 2003.

Online Resources:

1. Introduction to Hybrid and Electric vehicles by Dr. Praveen Kumar and Prof. S. Majhi (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/108/103/108103009/)

Department Elective Courses Offered by Thermal Engineering Section

Course Code: ME5162	ADVANCED COMPUTATIONAL FLUID DYNAMICS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Derive the governing equations and understand the behaviour of the equations.
CO2	Derive algebraic equations using finite volume methods for various fluid flow and heat transfer problems.
CO3	Solve systems of linear and non-linear equations using state of the art iterative algorithms.
CO4	Analyze the error and uncertainty in numerical models used for various algorithms.
CO5	Model the radiation heat transfer and turbulent flow problems using advanced techniques.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3		1
CO2	2	2	3	3		1
CO3	2	2	3	3		1
CO4	2	2	3	3		1
CO5	2	2	3	3		1

Syllabus:

Introduction: Revision of Fluid Mechanics and Heat transfer fundamentals.

Governing equations of fluid dynamics: The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Finite volume method for diffusion problems: Derivation of equations for 1-D, 2-D and 3-D steady state diffusion, Solution of 1-D, 2-D and 3-D steady state heat conduction of slab.

Finite volume method for convection-diffusion problems: Conservativeness, Boundedness and Transportiveness, Central, Upwind, Hybrid and Power law schemes, QUICK and TVD schemes.

Pressure Velocity Coupling in steady flows: Staggered grid, SIMPLE algorithm, Assembly of a complete method, SIMPLER, SIMPLEC and PISO algorithms, Worked examples of the above algorithms.

Solution of discretized equations: Direct and Indirect or iterative methods, TDMA algorithm, Point-iterative methods (Jacobi method, Gauss-Seidel Method, Relaxation method), Multigrid methods

Finite volume method for 1-D unsteady flows: 1D unsteady heat conduction (Explicit, Crank-Nicolson and fully implicit schemes), Transient problems with QUICK, SIMPLE schemes, Implementation of boundary conditions: Inlet, Outlet, and Wall boundary conditions, Pressure boundary condition, Cyclic or Symmetric boundary condition.

Errors and uncertainty in CFD modelling: Numerical errors, Input uncertainty, Physical model uncertainty, Verification and validation, Guidelines for best practices in CFD, Reporting and documentation of CFD results.

CFD modelling of turbulent flows: Characteristics of turbulence, Effect of turbulent fluctuations on mean flow, Turbulent flow calculations, Turbulence modelling, Large Eddy Simulation, Direct Numerical Simulation.

Grid Generation: Unstructured grid generation, Domain nodalization, Domain triangulation, Advancing front methods, The Delaunay method, The respective algorithms with examples.

CFD for radiation heat transfer: Governing equations for radiation heat transfer, Popular radiation calculation techniques using CFD, The Monte-Carlo method, The discrete transfer method, Raytracing, The discrete ordinates method.

Learning Resources:

Text Books:

1) An introduction to computational fluid dynamics: the finite volume method, H.K. Versteeg, W. Malalasekera, Longman Group, England, 2007, 2nd Edition.
2) Computational Fluid Dynamics the Basics with Applications, Anderson. J.D(Jr), McGraw Hill Education, 2017.

Reference Books:

1) Computational Fluid Dynamics, Hoffman, K.A., and Chiang, S.T., Vol. I, II and III, Engineering Education System, 2000, 4th edition.
2) Computational Fluid Dynamics, Chung, T.J., Cambridge University Press, 2014, 2nd Edition.
3) Computational Fluid Mechanics and Heat Transfer, Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., CRC Press, 2013, 3rd Edition.

Online Resources:

1) Computational Fluid Dynamics using Finite Volume Method by Dr. Kameswararao Anupindi (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106294/)
2) Foundations of Computational Fluid Dynamics by Prof. S. Vengadesan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106186/)
3) Computational Fluid Dynamics by Prof. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105045/)

Course Code: ME5166	DESIGN OF HEAT TRANSFER EQUIPMENT	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand the physics and the mathematical treatment of typical heat exchangers.
CO2	Apply LMTD and Effectiveness - NTU methods in the design of heat exchangers
CO3	Design the shell and tube heat exchanger.
CO4	Apply the principles of boiling and condensation in the design of boilers and condensers
CO5	Design cooling towers from the principles of psychrometry

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	1	2		
CO2	3	2	2	2	2	3
CO3	3	2	2	3	2	2
CO4	3	2	3	3	2	3
CO5	3	2	2	3		2

Syllabus:

Introduction to Heat Exchangers: Definition, Applications, Various methods of classification of heat exchangers with examples.

Governing Equation for heat exchangers: Derivation from steady-state steady-flow considerations.

Mathematical treatment of Heat Exchangers: Concept of Overall Heat Transfer Coefficient, Derivation of the concerned equations, Fouling, Fouling Factor, Factors contributing to fouling of a heat exchanger, Ill-Effects of fouling, Numerical Problems.

Concept of Logarithmic Mean Temperature Difference: Expression for single-pass parallel-flow and single-pass counter flow heat exchangers – Derivation from first principles, Special Cases, LMTD for a single-pass cross-flow heat exchanger – Nusselt's approach, Chart solutions of Bowman et al. pertaining to LMTD analysis for various kinds of heat exchangers, Numerical Problems, Arithmetic Mean Temperature Difference [AMTD], Relation between AMTD and LMTD, Logical Contrast between AMTD and LMTD, LMTD of a single-pass heat exchanger with linearly varying overall heat transfer coefficient [U] along the length of the heat exchanger.

Concept of Effectiveness: Effectiveness-Number of Transfer Units Approach, Effectiveness of single-pass parallel-flow and counter-flow heat exchangers, Physical significance of NTU, Heat capacity ratio, Different special cases of the above approach, Chart solutions of Kays

and London pertaining to Effectiveness-NTU approach, Numerical Problems.

Hair-Pin Heat Exchangers: Introduction to Counter-flow Double-pipe or Hair-Pin heat exchangers, Industrial versions of the same, Film coefficients in tubes and annuli, Pressure drop, Augmentation of performance of hair-pin heat exchangers, Series and Series-Parallel arrangements of hair-pin heat exchangers, Comprehensive Design Algorithm for hair-pin heat exchangers, Industrial standards, Numerical Problems.

Shell and Tube Heat Exchangers: Single-Pass, One shell-Two tube [1S-2T] and other heat exchangers, Industrial versions of the same, Classification and Nomenclature, Baffle arrangement, Types of Baffles, Tube arrangement, Types of tube pitch lay-outs, Shell and Tube side film coefficients, Pressure drop calculations, Numerical Problems.

Plate heat exchangers: Introduction, Mechanical Features - Plate pack and the frame, Plate types, Advantages and performance limits, Passes and flow arrangements, Heat transfer and pressure drop calculations, Numerical problems

Principles of Boilers and Condensers: Boiling, Fundamentals and Types of boiling – Pool boiling curve, Various empirical relations pertaining to boiling, Numerical problems on the above, Condensation – Classification and Contrast, Types of condensers, Nusselt's theory on laminar filmwise condensation, Empirical Refinements, Several empirical formulae, Numerical problems.

Cooling Towers: Cooling towers – basic principle of evaporative cooling, Psychrometry, fundamentals, Psychrometric chart, Psychrometric Processes, Classification of cooling towers, Numerical problems.

Learning Resources:

Text Books:

1. Compact Heat Exchangers, Kays, W. M. and London, A. L., McGraw – Hill, New York, 2nd Edition, 1998.
2. Fundamentals of Heat Exchanger Design, Shah, R. K. and Sekulic, D. P., John Wiley and Sons, New Jersey, 2003.

Reference Books:

1. Fundamentals of Heat and Mass Transfer, Incropera, F. P. and Dewitt, D. P., 7th Edition, John Wiley and Sons, New York, 2013.

Online Resources:

1. Heat Exchangers: Fundamentals And Design Analysis by Prof. Indranil Ghosh, IIT Kharagpur, NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105248/)

Course Code: ME5170	ESSENTIALS OF ENTREPRENEURSHIP	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand entrepreneurship and entrepreneurial process and its significance in economic development
CO2	Develop an idea of the support structure and promotional agencies assisting ethical entrepreneurship
CO3	Identify entrepreneurial opportunities, support and resource requirements to launch a new venture within legal and formal framework
CO4	Develop a framework for technical, economic and financial feasibility to prepare a written business plan
CO5	Understand the stages of establishment, growth, barriers, and causes of sickness in industry to initiate appropriate strategies for operation, stabilization and growth

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	1			2
CO2	2	3	3			3
CO3	1	2	1		2	2
CO4	2	3	3		2	3
CO5	3	2	1		2	3

Syllabus:

Entrepreneur and Entrepreneurship: Introduction; Entrepreneur and Entrepreneurship; Role of entrepreneurship in economic development; Entrepreneurial competencies and motivation; EDP models, Institutional Interface for Small Scale Industry/Enterprises.

Business Idea generation: Opportunity Scanning and Identification; Creativity and product development process; The technology challenge – Innovation in a knowledge-based economy, sources of innovation pulses – Internal and external; Drucker's 7 sources of innovation impulses, General innovation tools, role of innovation during venture growth; Market survey and assessment; choice of technology and selection of site.

Planning a Start-up Enterprise: Forms of business organization/ ownership; Financing new enterprises – sources of capital for early-stage technology companies; Techno Economic Feasibility Assessment; Preparation of Business Plan for grants, loans and venture capital.

Operational Issues for new enterprises: Financial management issues; Operational/ project management issues in SSE; Marketing management issues in SSE; Relevant business and industrial Laws.

Performance appraisal and growth strategies: Strategies to anticipate and avoid pitfalls associated with launching and leading a technology venture; Management performance assessment and control; Causes of Sickness in SSI, Strategies for Stabilization and Growth.

Learning Resources:

Text Books:

1. Technology Ventures: From Ideas to Enterprise, Byers, Dorf, and Nelson, McGraw Hill. ISBN-13: 978-0073380186., 2010
2. Entrepreneurship: Successfully Launching New Ventures, Bruce R Barringer and R Duane Ireland, Pearson Edu., 2013 3rd ed.
3. Entrepreneurial Development, S.S. Khanka, S Chand & Company Ltd., 2012, 4th ed.
4. Entrepreneurship: A South-Asian Perspective, D.F. Kuratko and T.V. Rao, Cengage Learning, 2013.

Reference Books:

1. A Handbook for New Entrepreneurs, Entrepreneurship Development Institute of India, Ahmedabad, 1988.
2. The practice of entrepreneurship, G.G. Meredith, R.E. Nelson & P.A. Neck, ILO, 1982
3. Management of Small-Scale Enterprises, Dr. Vasant Desai, Himalaya Publishing House, 2004.

Course Code: ME5171	COMBUSTION AND EMISSION CONTROL	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand the concepts of combustion phenomena in IC Engines and Gas Turbines.
CO2	Apply the knowledge of adiabatic flame temperature in the design of combustion devices.
CO3	Identify the phenomenon of flame stabilization in laminar and turbulent flames.
CO4	Analyse the possible harmful emissions and measure as per the legislation standards.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	3	2	2
CO2	2	1	2	2	1	2
CO3	2	1	2	2	1	2
CO4	2	2	1	1	2	2

Syllabus:

Combustion Principles: Combustion – Combustion equations, heat of combustion - Theoretical flame temperature – chemical equilibrium and Dissociation -Theories of Combustion - Flammability Limits - Reaction rates – Laminar and Turbulent Flame Propagation in Engines. Introduction to spray formation and characterization.

Combustion in S.I. Engines: Stages of combustion, normal and abnormal combustion, knocking, Variables affecting Knock, Features and design consideration of combustion chambers. Flame structure and speed, Cyclic variations, Lean burn combustion, Stratified charge combustion systems. Heat release correlations.

Combustion In C.I. Engines: Stages of combustion, vaporization of fuel droplets and spray formation, air motion, swirl measurement, knock and engine variables, Features and design considerations of combustion chambers, delay period correlations, heat release correlations, Influence of the injection system on combustion, Direct and indirect injection systems.

Combustion in Gas Turbines: Flame stability, Re-circulation zone and requirements - Combustion chamber configurations, Cooling, Materials.

Pollutant Emissions from IC Engines: Introduction to clean air, Pollutants from SI and CI Engines: Carbon monoxide, UBHCs, Oxides of nitrogen (NO-NOX) and Particulate Matter, Mechanism of formation of pollutants, Factors affecting pollutant formation. Measurement of engine emissions-instrumentation, Pollution Control Strategies, Emission norms-EURO and Bharat stage norms. Effect of emissions on environment and human beings. Brief treatment on harmful emissions from Gas Turbines, Gas turbine-NOx control (DLE - Dry Low Emission).

Control Techniques for Reduction of Harmful Emissions from IC Engines: Emission

control measures for SI and CI engines and gas turbines. Design modifications – Optimization of operating factors – Fuel modification – Evaporative emission control - Exhaust gas recirculation – SCR – Fumigation – Secondary Air injection – PCV system – Particulate Traps-Thermal reactors – Catalytic converters – Catalysts – Use of unleaded petrol-brief treatment.

Test Procedure, Instrumentation & Emission Measurement: Definition of Vehicle Driving Cycle-Test procedures INDIAN DRIVING CYCLE(IDC) – ECE Test cycle – FTP Test cycle – NDIR analyser – Flame ionization detector – Chemiluminescent analyser – Continuous Volume Sampling-Dilution tunnel – Gas chromatograph – Smoke meters.

Learning Resources:

Text Books:

1. Internal Combustion Engine Fundamentals, John.B. Heywood , McGraw Hill Co., 2018, II Edition.
2. Gas Turbine Theory, Cohen, H, Rogers, G, E.C, and Saravanamuttoo, H.I.H., Pearson, Pearson, 2019,7th Edition.

Reference Books:

1. Introduction to Combustion, Stephen, R. Turns., McGraw Hill, 2005.
2. Engine Emissions Fundamentals and Advances in Control, B.P. Pundir B P Narosa Publications. 2017, 2/E
3. Combustion: Physical and Chemical Fundamentals, Modelling and Simulation, Experiments, Pollutant Formation Warnatz, Ulrich Maas and Robert W. Dibble, Springer, 2012.

Online Resources:

1. Emission Standards, www.dieselnet.com
2. Automotive Emission Test Procedures, www.araiindia.com

Department Elective Courses Offered by Materials and Systems Engineering Design

Course Code: ME5664	NON-DESTRUCTIVE TESTING AND EVALAUTION	Credits 3-0-0: 3

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Understand the principles of NDT methods
CO2	Identify appropriate non destructive testing methods for failure identification
CO3	Utilize radiography to identify underlying failure site
CO4	Analyse flaws using advanced eddy current methods
CO5	Utilize acoustic emission to identify leaks

Course Articulation Matrix:

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

Syllabus:

Introduction to NDT, Liquid penetrant test: Physical Principles, Procedure for penetrant testing, penetrant testing materials, Penetrant testing methods, sensitivity, Applications and limitations, typical examples.

Ultrasonic testing: Basic properties of sound beam, Ultrasonic transducers, Inspection methods, Techniques for normal beam inspection, Techniques for angle beam inspection, Flaw characterization techniques, Applications of ultrasonic testing, Advantages and limitations.

Thermography: Basic principles, Detectors and equipment, techniques, applications.

Radiography: Basic principle, Electromagnetic radiation sources, radiographic imaging, Inspection techniques, applications, limitations, typical examples.

Eddy current test: Principles, instrumentation for ECT, techniques, sensitivity, advanced eddy Current test methods, applications, limitations.

Acoustic emission: Principle of AET, Technique, instrumentation, sensitivity, applications, Acoustic emission technique for leak detection.

Magnetic particle inspection: Principle of MPT, Procedure used for testing a component, sensitivity, limitations.

NDT of Composites: Codes and Conventions - Difficulties - Few Case Studies.

Learning Resources:

Text Books:

1. Non Destructive Evaluation: Theory, Techniques and Applications, Peter J. Shull , Marcel Dekkar, 2002.
2. Non Destructive Testing Hand Book, Vol. 4, P. Mclntire (Ed.), American Society for Non Destructive Society, 2010

Reference Book:

1. Non Destructive Testing and Quality Control, ASM Metals Hand Book, Vol. 17, ASM, 1989.

Department Elective Courses Offered by Computer Integrated Manufacturing Section

Course Code: ME5367	RELIABILITY ENGINEERING	Credits 3-0-0: 3

Pre-requisites:

Course Outcomes:

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

CO1	Understand the concepts of Reliability, Availability and Maintainability
CO2	Develop hazard-rate models to know the behavior of components.
CO3	Build system reliability models for different configurations.
CO4	Assess reliability of components & systems using field & test data.
CO5	Implement strategies for improving reliability of repairable and non-repairable systems.

Course Articulation Matrix:

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

Syllabus:

Introduction: Probabilistic reliability, failures and failure modes, repairable and non-repairable items, pattern of failures with time, reliability economics.

Component Reliability Models: Basics of probability & statistics, hazard rate & failure rate, constant hazard rate model, increasing hazard rate models, decreasing hazard rate model, time-dependent & stress-dependent hazard models, bath-tub curve.

System Reliability Models: Systems with components in series, systems with parallel components, combined series-parallel systems, k-out-of-m systems, standby models, load-sharing models, stress-strength models, reliability block diagram.

Life Testing & Reliability Assessment: Censored and uncensored field data, burn-in testing, acceptance testing, accelerated testing, identifying failure distributions & estimation of parameters, reliability assessment of components and systems.

Reliability Analysis & Allocation: Reliability specification and allocation, failure modes and effects and criticality analysis (FMECA), fault tree analysis, cut sets & tie sets approaches;

Maintainability Analysis: Repair time distribution, MTBF, MTTR, availability, maintainability, preventive maintenance.

Text Books:

1. An Introduction to Reliability and Maintainability Engineering, Ebeling CE, TMH, New Delhi, 2004.
2. Practical Reliability Engineering, O'Connor P and Kleymer A, Wiley, 2012

Course Code: ME5368	INDUSTRY 4.0 and IIoT	Credits 3-0-0: 3

Pre-requisites: Nil

Course Outcomes:

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

CO1	Explore how Industry 4.0 will change the current manufacturing technologies and processes by digitizing the value chain
CO2	Understand the drivers and enablers of Industry 4.0
CO3	Learn about various IIoT-related protocols
CO4	Build simple IIoT Systems using Arduino and Raspberry Pi

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3	1	2	
CO2	2		2	2	1	
CO3	2		3	3		
CO4			3	3	1	2

Syllabus:

Introduction to Industry 4.0: Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Mass Customization, Smart and Connected Business Perspective, Smart Factories, Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals- Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT.

Elements of IIoT: Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.

IIoT Application Development : Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Device data storage- Unstructured data storage on cloud/local server, Authentication, authorization of devices. Case Studies: IoT case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Learning Resources:

Text Books:

1. Introduction to Industrial Internet of Things and Industry 4.0, Sudip Misra, Chandana Roy, Anandarup Mukherjee, CRC Press, 2020.
2. A Hands on Approach", Vijay Madisetti, Arshdeep Bahga, Ïnternet of Things, University Press, 2009.
3. Introduction to Internet of Things: A practical Approach", Dr. SRN Reddy, Rachit Thukral and Manasi Mishra, ETI Labs,2010
4. The Internet of Things: Enabling Technologies, Platforms, and Use Cases", Pethuru Raj and Anupama C. Raman, CRC Press, 2012
5. Designing the Internet of Things", Adrian McEwen, Wiley, 2015

Reference Books:

1. Internet of Things: Architecture and Design, Raj Kamal, McGraw Hill., 2005.
2. Getting Started with the Internet of Things, Cuno Pfister, O Reilly Media, 2007.

Online :

1. https://onlinecourses.nptel.ac.in/noc21_cs17/preview

Course Code: ME5369	DESIGN AND ANALYSIS OF EXPERIMENTS	Credits 3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Formulate objective(s) and identify key factors in designing experiments for a given problem.
CO2	Develop appropriate experimental design to conduct experiments for a given problem.
CO3	Analyze experimental data to derive valid conclusions.
CO4	Optimize process conditions by developing empirical models using experimental data.
CO5	Design robust products and processes using parameter design approach.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	2		1
CO2	3		2	3		1
CO3	3	1	2	3		1
CO4	3		2	3		1
CO5	2		2	3		1

Syllabus:

Fundamentals of Experimentation: Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation; Simple Comparative Experiments: Basic concepts of probability and statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA;

Experimental Designs: Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays & interaction tables, modifying the orthogonal arrays, selection of suitable orthogonal array design, analysis of experimental data;

Response Surface Methodology: Concept, linear model, steepest ascent, second order model, regression;

Taguchi's Parameter Design: Concept of robustness, noise factors, objective function & S/N ratios, inner-array and outer-array design, data analysis

Learning Resources:

Text Books:

1.Design and Analysis of Experiments, Montgomery DC, 7th Edition, John Wiley & Sons, NY, 2008

2.Taguchi Techniques for Quality Engineering, Ross PJ, McGraw-Hill Book Company, NY, 2008.

Course Code: ME5370	PROJECT MANAGEMENT	Credits 3-0-0: 3

Pre-requisites:

Course Outcomes:

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

CO1	Understand the importance of projects and its phases.
CO2	Analyze projects from marketing, operational and financial perspectives.
CO3	Evaluate projects based on discount and non-discount methods.
CO4	Develop network diagrams for planning and execution of a given project.
CO5	Apply crashing procedures for time and cost optimization.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		2	2		2
CO2	3	1	2	2		2
CO3	2	1	2			2
CO4	2	1	2	2	2	2
CO5	2	1	2	2		2

Syllabus:

Introduction: Introduction to Project Management, History of Project Management, Project Life Cycle.

Project Analysis: Facets of Project Analysis, Strategy and Resource Allocation, Market and Demand Analysis, Technical Analysis, Economic and Ecological Analysis.

Financial Analysis: Financial Estimates and Projections, Investment Criteria, Financing of Projects.

Network Methods in PM: Origin of Network Techniques, AON and AOA differentiation, CPM network, PERT network, other network models.

Optimization in PM: Time and Cost trade-off in CPM, Crashing procedure, Scheduling when resources are limited.

Project Risk Management: Scope Management, Work Breakdown Structure, Earned Value Management, Project Risk Management.

Text Books:

1. Project: A Planning Analysis, Prasanna Chandra, Tata McGraw Hill Book Company, New Delhi, 4th Edition,2009.
2. Project Management, Cleland, Gray and Laudon, Tata McGraw Hill Book Company, New Delhi, 3rd Edition, 2007.
3. Larson Project Management , Clifford F. Gray, Gautam V. Desai, Erik W., Tata McGraw-Hill Education, 2010

Course Code: ME5371	ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR MECHANICAL SYSTEMS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand the core concepts of Mechanical Systems in the context of Industry 4.o
CO2	Apply AI, ML and Deep Learning concepts on Various Mechanical Systems
CO3	Apply the statistical and optimization techniques on Mechanical Systems
CO4	Evaluate the Mechanical System performance using simulation and experimental analysis

Course Articulation Matrix:

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

Syllabus:

Introduction to Mechanical Systems evolution in the context of Industry 4.0, Key issues: Adaptability, Intelligence, Autonomy, Safety, Sustainability, Interoperability, Flexibility of Mechanical Systems.

Introduction of Statistics; Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, centre limit theorem, sampling, sampling methods; Inferential Statistics: Hypothesis testing, confidence level, degree of freedom, P-value, Chi-square test, ANOVA, Correlation V's Regression, Uses of Correlation and regression.

Artificial Intelligence: Brief review of AI history, Problem formulation: Graph structure, Graph implementation, state space representation, search graph and search tree, Search Algorithms: random search, Depth-first, breadth-first search and uniform-cost search. Heuristic: Best first search, A* and AO* algorithm, generalization of search problems. Ontology; Fuzzy; Meta-heuristics.

Machine Learning: Overview of supervised and unsupervised learning; Supervised Learning: Linear Regression, Non-linear Regression Model evaluation methods, Logistic Regression, Neural Networks; Unsupervised Learning: K-means clustering, C-means Clustering. Convolutional Neural Networks (CNN), Pooling, Padding Operations, Interpretability in CNNs, Limitations in CNN. Cases with respect to different mechanical systems.

Introduction to Raspberry Pi; Installation of Raspbian OS on Raspberry Pi; Controlling LED using Raspberry Pi; Integrating IR Sensor with Raspberry Pi; Controlling LED with IR Sensor; Integrating Temperature and amp; Humidity Sensor with Raspberry Pi read Current Environment Values, Collecting the sensor data using Raspberry Pi; Matlab toolboxes - Simulink, Mechanical Systems implementation: From features to software components, Mapping software components to ECUs.

Learning Resources

Text Books:

1. Rajkumar, Dionisio De Niz ,and Mark Klein, Cyber-Physical Systems, Wesley Professional.
2. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015.
3. Robert Levine et al., “A Comprehensive guide to AI and Expert Systems”,McGraw Hill Inc, 1986.
4. E. A. Lee and S. A. Seshia, “Introduction to Embedded Systems: A Cyber-Physical Systems Approach”, 2011.
5. C. Cassandras, S. Lafortune, “Introduction to Discrete Event Systems”, Springer 2007.
6. Constance Heitmeyer and Dino Mandrioli, “Formal methods for real-time computing”, Wiley publisher, 1996.
7. Montgomery Douglas, 2017. Design of Experiments, John Wiley and Sons, Inc.

Department Elective Courses Offered by Machine Design Section

Course Code: ME5462	CONDITION MONITORING AND FAULT DIAGNOSTICS	Credits 3-0-0: 3

Course Outcomes:

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

CO1	Understand effective maintenance schemes in industries.
CO2	Apply vibration monitoring techniques for system diagnoses.
CO3	Apply oil analysis technique to diagnose the wear debris.
CO4	Identify nonconventional methods for machine diagnoses.
CO5	Develop modern technologies for effective plant maintenance.

Course Articulation Matrix:

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

Syllabus:

Vibration based condition monitoring: Introduction, Type of failures, investigation and occurrences, Service failures, Principles of predictive maintenance, Predictive maintenance techniques, sensors for fault detection, Vibration transducers, Vibration basics, Spring-mass system: mass, stiffness, damping, System response, Nature of vibration, Harmonics, Limits and standards of vibration.

Data acquisition and analysis: Introduction, Vibration sensors, characteristics and mountings Collection of vibration signal, Vibration signature of active systems, Vibration monitoring equipment, Critical vibration levels, Conversion of vibrations to electrical signal, The fast Fourier transform (FFT) analysis, Frequency analysis techniques, Derived functions, Time waveform analysis, Phase signal analysis.

Machinery fault diagnosis and correcting faults: Introduction, Commonly witnessed machinery faults diagnosed, Simple vibration, Belt drives, Gear excitation, Rolling elements bearing, Balancing, Alignment, Resonance vibration control with dynamic absorbers.

Wear debris analysis: Introduction, Oil fundamentals, sampling methods, lubricant properties, Contaminants in used lubricating oils, Contaminants monitoring techniques, Spectrometric oil analysis, Magnetic chip detectors, Ferrograph particle precipitation, XRF, Temperature analysis.

Other predictive maintenance techniques: Performance trend monitoring, Performance monitoring systems, Introduction to non-destructive techniques, Ultrasound, Infrared thermography, Eddy current, Introduction to structural health monitoring

Learning Resources:

1. Rao J. S., Vibration Condition Monitoring, Narosa Publishing House, 2/e 2000.
2. Isermann R., Fault Diagnosis Application, Springer-Verlag Berlin, 2011.
3. Allan Davis, Hand book of Condition Monitoring, Chapman and Hall, 2000.
4. Choudary K K., Instrumentation, Measurement and Analysis, Tata McGraw Hill.
5. Collacott, R. A., Mechanical Faults Diagnosis, Chapman and Hall, London, 1990
6. Vibration and Acoustics, C Sujatha, Tata McGraw Hill, 2017

Course Code: ME5466	TRIBOLOGY IN DESIGN	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student shall be able to:

CO1	Analyze properties of lubricant and select proper lubricant for a givenapplication.
CO2	Identify tribological performance parameters of sliding contact in different lubrication regimes
CO3	Design and select appropriate bearings for a given application
CO4	Predict the type of wear and volume of wear in metallic and polymer surfaces.

Course Articulation Matrix:

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

Syllabus:

Introduction: Overview of the course, history and basic concept of friction, wear and lubrication.

Introduction to Concept of tribodesign: Specific principles of tribodesign; Tribological problems in machine design: Plain sliding bearings, Rolling contact bearings, Piston, piston rings and cylinder liners, Cam and cam followers, Friction drives, Involute gears, Hypoid gears, Worm gears, Seals.

Friction and Wear: Origins of sliding friction: Contact between bodies in relative motion, Friction due to adhesion, Friction due to ploughing, Friction due to deformation, Energy dissipation during friction, Friction under complex motion conditions, Types of wear and their mechanisms: Adhesive wear, Abrasive wear, Wear due to surface fatigue, Wear due to chemical reactions, Sliding contact between surface asperities, Wear in lubricated contacts, Wear and friction of metallic, polymeric and ceramic composite materials

Lubrication modes and Theories of hydrodynamic lubrication: Lubricants-Types of lubricants, Objectives of lubricant, Physical properties oflubricants, Selection of lubricant. Modes of lubrication - hydrodynamic, hydrostatic, Elasto-hydrodynamic, mixed and boundarylubrication, Reynolds' equation, Applications of hydrodynamic lubrication theory - Journal bearing and Inclined thrust pad bearing, Hydrodynamic lubrication of roughened surfaces, Theories of Externally pressurized lubrication, Squeeze-film lubrication, Elasto-hydrodynamic lubrication and air lubricated bearing.

Lubrication regimes and bearings design: Rheological lubrication regime,Functional lubrication regime, Bearing types and its selection. Bearings design.

Tribo Design of Machine Elements: Lower Kinematic pairs – Sliding bearings,

mechanical face seal, clutches and brakes; Higher Kinematic pairs – Ball bearing, Roller bearing, Gear contacts. Case studies.

Learning Resources:

1. Engineering Tribology, Stachowaik, G.W., Batchelor, A.W., 3rd Ed., Elsevier, 2010.
2. Tribology in Machine Design, TA Stolarski, Butterworth-Heinemann, 2000.
3. Engineering Tribology, Williams JA, Oxford Univ. Press, 2001.
4. Introduction to bearings, Majumdar B.C, S. Chand & Co., Wheeler publishing, 1999.
5. Fluid film lubrication theory and design, Andras Z. Szeri, Cambridge Universitypress, 1998.
6. Basic lubrication theory, Cameron A, Ellis Horwood Ltd., 2002.
7. Tribology Hand Book, Neale MJ, CBS Publications, 2012.
8. Mechanical Vibrations, Venkatachalam R., PHI Publications, 2018

Course Code: ME5467	ADVANCED COMPOSITE TECHNOLOGIES	Credits 3-0-0: 3

Course Outcomes:

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

CO1	Understand composite material and their reinforcements
CO2	Select constituent materials to develop appropriate composites
CO3	Analyze interfaces of composites for predicting their mechanical properties.
CO4	Develop metal matrix, ceramic matrix and polymer matrix composites with calculated values of constituents
CO5	Analyze the performance of automobile component material

Course Articulation Matrix:

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

Syllabus:

Introduction: Overview of the course, history and basic concept of composites, Types and constituents, reinforcement and matrices, interface and mechanism of strengthening.

Fundamental concepts: Definition and Classification of Composites, particulate and dispersion hardened composites, continuous and discontinuous fibre reinforced composites MMC, PMC, CMC. Automobile component materials

Metal Matrix Composites Processing: Liquid state processes, solid state processes and insitu processes.

Interface: Role, reactions, bonding mechanisms and bond strength.

Properties and applications: Strength, stiffness, creep, fatigue and fracture; thermal, damping and tribological properties.

Polymer Matrix Composites Processing: Hand layup and spray technique, filament winding, pultrusion, resin transfer molding, bag and injection molding, sheet molding compound.
Matrix resins-thermoplastics and thermosetting matrix resins.Reinforcing fibers- Natural fibers (cellulose, jute, coir etc.), carbon fiber, glass fiber, Kevlar fiber, etc.Particulate fillers-importance of particle shape and size.Coupling agents-surface treatment of fillers and fibers, significance of interface in composites. short and continuous fibre reinforced composites, critical fibre length, and anisotropic behavior. Polymer composites applications in Automobile industry.

Ceramic Matrix Composites Processing: Cold pressing & sintering, hot pressing reaction bonding processes, infiltration, in-situ chemical reaction, Sol-Gel and polymer pyrolysis, self-propagating high temperature synthesis. Carbon- carbon composites, Interfaces.

Rule of mixtures. Stress, strain transformations.
Nanocomposites: introduction to Nanocomposites, advantages disadvantages

Materials for Automobile bodies: Materials for considerations and use in automobile body structure- Steels, Aluminium alloys, Magnesium alloys, polymers and composites. Component manufacturing: material joining, Casting and forming techniques.
Heat Treatment processes: Annealing, Normalising, Ageing, solutionising, hardening, tempering
Surface Heat treatment : Carburising, zinc coating, Nitriding , cyaniding

Test methods: Quality assessment, physical and mechanical property characterization.

Learning Resources:

1. Composite Materials Science and Engineering, Chawla, Springer
2. An introduction to composite materials, Hull, Cambridge
3. ASM Handbook Composites, Steven L. Donaldson, Volume 21, 2001.
4. Composite Materials, Science and Engineering, Krishan K. Chawla, Springer, 2001.
5. Process Modelling in Composites Manufacturing, Suresh G. Advani, E. Murat Sozer, 2nd Ed. CRC Press, 2009
6. Materials for Automobile Bodies-Geoffrey Davies, 2nd Ed. Elsevier Science, 2003.

Course Code: ME5469	OPTIMIZATION METHODS FOR ENGINEERING DESIGN	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student shall be able to:

CO1	Formulate a design task as an optimization problem
CO2	Identify constrained and unconstrained optimization problems and solve using corresponding methods
CO3	Solve discontinuous optimization problems using special methods
CO4	Solve nonlinear optimization problems with evolutionary methods

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	1	2
CO2	2	2	3	3	2	2
CO3	3		3	3	3	2
CO4	3		3	3	3	2

Syllabus:

Introduction to Optimization in Design: Problem formulation, Optimization problems in Mechanical Engineering, Classification of methods for optimization

Single-variable Optimization: Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods.

Multiple-variable Optimization: Optimal criteria, Direct search methods (Box's, Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

Constrained Optimization: KKT conditions, Penalty method, Sensitivity analysis, Direct search methods for constrained optimization, quadratic programming, GRG method, Formulation and Case studies.

Specialized algorithms: Integer programming (Penalty function and branch-and- bound method), Geometric programming.

Evolutionary Optimization algorithm: Genetic algorithms, simulated annealing, Anti-colony optimization, Particle swarm optimization.

Multi-objective Optimization: Terminology and concepts, the concepts of Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA.

Case studies and Computer Implementation: Representative case studies for important methods and development of computer code for the same to solve problems.

Learning Resources:

1. Introduction to Optimum Design, Jasbir Arora, Academic Press, 2004
2. Optimization For Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, 2004.
3. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, Wiley,2001.

Department Elective Courses Offered by Manufacturing Engineering Section

Course Code: ME5265	MECHATRONICS AND ROBOTICS	Credits 3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Model, analyze and control engineering systems.
CO2	Select appropriate sensors, transducers and actuators to monitor and control the behavior of a process or product.
CO3	Develop PLC programmes for a given task.
CO4	Evaluate the performance of mechatronic systems.
CO5	Understand the evolution, classification, structures and drives for robots.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	3		
CO2	3	2	2	3	2	
CO3	2		2	3		
CO4	1	1	2	3		2
CO5	1		2	3		

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, History of Mechatronics, Scope and Significance of Mechatronics systems, elements of mechatronic systems, needs and benefits of mechatronics in manufacturing.

Sensors: Classification of sensors basic working principles, Displacement Sensor - Linear and rotary potentiometers, LVDT and RVDT, incremental and absolute encoders. Strain gauges. Force/Torque – Load cells. Temperature – Thermocouple, Bimetallic Strips, Thermistor, RTD Accelerometers, Velocity sensors – Tachometers, Proximity and Range sensors – Eddy current sensor, ultrasonic sensor, laser interferometer transducer, Hall Effect sensor, inductive proximity switch. Light sensors – Photodiodes, phototransistors, Flow sensors – Ultrasonic sensor, laser Doppler anemometer tactile sensors – PVDF tactile sensor, micro-switch and reed switch Piezoelectric sensors, vision sensor.

Actuators: Electrical Actuators : Solenoids, relays, diodes, thyristors, triacs, BJT, FET, DC motor, Servo motor, BLDC Motor, AC Motor, stepper motors. Hydraulic & Pneumatic devices – Power supplies, valves, cylinder sequencing. Design of Hydraulic & Pneumatic circuits. Piezoelectric actuators, Shape memory alloys.

Basic System Models & Analysis: Modelling of one and two degrees of freedom Mechanical, Electrical, Fluid and thermal systems, Block diagram representations for these systems. Dynamic Responses of System: Transfer function, Modelling Dynamic systems, first order systems, second order systems.

Digital Electronics: Number systems, BCD codes and arithmetic, Gray codes, self-complimenting codes, Error detection and correction principles. Boolean functions using Karnaugh map, Design of combinational circuits, Design of arithmetic circuits. Design of Code converters, Encoders and decoders.

Signal Conditioning: Operational amplifiers, inverting amplifier, differential amplifier, Protection, comparator, filters, Multiplexer, Pulse width Modulation Counters, decoders. Data acquisition – Quantizing theory, Analog to digital conversion, digital to analog conversion.

Controllers: Classification of control systems, Feedback, closed loop and open loop systems, Continuous and discrete processes, control modes, Two step Proportional, Derivative, Integral, PID controllers.

PLC Programming: PLC Principles of operation PLC sizes PLC hardware components I/O section Analog I/O section Analog I/O modules, digital I/O modules CPU Processor memory module Programming. Ladder Programming, ladder diagrams, timers, internal relays and counters, data handling, analogue input and output. Application on real time industrial automation systems.

Case studies of Mechatronics systems: Pick and place robot, Bar code, Engine Management system, Washing machine etc.

Robotics: Introduction to Robotics, Robot anatomy physical configurations, Manipulator, Kinematics, Technical features. Programming of Mobile robot, robot programming language, end effecters.

Learning Resources:

Text Books:

1. Mechatronics, W. Bolton, 5 th edition, Addison Wesley Longman Ltd, 2010
2. Mechatronics System Design, Devdas Shetty & Richard Kolk, 3rd edition. PWS Publishing, 2009.
3. Introduction to Mechatronics and Measurement systems, Alciatore David G &Histand Michael B, 4th edition, Tata McGraw Hill, 2006.

Reference Resources:

1. Introduction to Robotics: Analysis, Systems, Applications, Saeed B Niku, 2nd edition, Pearson Education India, PHI, 2003.

Online Sources

1. http://video_demos.colostate.edu/mechatronics
2. http:// mechatronics.me.wisc.edu

Course Code: ME5266	PRECISION MANUFACTURING	Credits 3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Understand the concept of accuracy and precision
CO2	Apply fits and tolerances for parts and assemblies as per ISO standards.
CO3	Evaluate the machine tool and part accuracies.
CO4	Estimate the surface quality of machined components

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	3	2	
CO2	3		3	3	2	
CO3	3		3	3	2	
CO4	2		2	2	2	

Syllabus:

Accuracy and Precision: Introduction - Accuracy and precision – Need – application of precision machining- alignment testing of machine tools, accuracy of numerical control system, specification of accuracy of parts and assemblies.

Tolerance and fits: Tolerance and fits, hole and shaft basis system, types of fits- Types of assemblies-probability of clearance and interference fits in transitional fits.

Concept of part and machine tool accuracy: Specification of accuracy of parts and assemblies, accuracy of machine tools, alignment testing of machine tools.

Errors during machining: Errors due to compliance of machine-fixture-tool-work piece (MFTW) System, theory of location, location errors, errors due to geometric inaccuracy of machine tool, errors due to tool wear, errors due to thermal effects, errors due to clamping. Statistical methods of accuracy analysis.

Surface roughness: Definition and measurement, surface roughness indicators (CLA, RMS, etc,.) and their comparison, influence of machining conditions, methods of obtaining high quality surfaces, Lapping, Honing, Super finishing and Burnishing processes.

Learning resources:

Text Books:

1. Precision Engineering in Manufacturing, R.L.Murty, New Age International Publishers, 1996.
2. Fundamentals of Process Engineering, V.Kovan, Foreign Languages Publishing House, Moscow, 1975

Reference books:

1. Process Engineering for Manufacture, Eary and Johnson, Prentice Hall, 1962.
2. Dimensional control in Precision Manufacturing, J.L.Gadjala, McGraw Hill Publishers, 2012.

Online resources:

1. https://www.nptel.ac.in/
2. https://precisionmfg.com/
3. https://cmti.res.in/precision-manufacturing-and-process-engineering/

Department Elective Courses Offered by Additive Manufacturing Section

Course Code: ME5763	RE- ENGINEERING	Credits 3-0-0: 3

Pre-requisites: -NIL-

Course Outcomes:

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

CO1	Identify the steps involved in re-engineering of a given component.
CO2	Design an existing component with suitable modifications as per customer's requirements.
CO3	Select and configure a suitable re-engineering system for inspection and manufacturing.
CO4	Apply the re-engineering techniques in aerospace, automobile and medical sectors.

Course Articulation Matrix:

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

Detailed Syllabus:

Introduction to reverse engineering, Re-Engineering–The Generic Process

Geometric Modelling using Point Cloud Data: Point Cloud acquisition, Surface Modelling from a point clouds, Meshed or Faceted Models, Planar Contour Models, Points to Contour Models, Surface Models, Segmentation and Surface Fitting for Prismatic objects and Free Form Shapes.

Methodologies and Techniques for Re-Engineering: The Potential for Automation with 3-D Laser Scanners, What Is Not Re-Engineering, What is Computer-aided (Forward) Engineering, What Is Computer-aided Reverse Engineering, Computer Vision and Re-Engineering.

Re-Engineering–Hardware and Software: Contact Methods Noncontact Methods, Destructive Method.

Selecting a Re-Engineering System: The Selection Process, Some Additional Complexities, Point Capture Devices, Triangulation Approaches, "Time-of-flight" or Ranging Systems, Structured-light and Stereoscopic Imaging Systems, issues with Light-based Approaches, Tracking Systems, Internal Measurement Systems, X-ray Tomography, Destructive Systems, Some Comments on Accuracy, Positioning the Probe, Post processing the Captured Data, Handling Data Points, Curve and Surface Creation, Inspection

Applications, Manufacturing Approaches.

Integration between Re-Engineering and Additive Manufacturing: Modeling Cloud Data in Re-Engineering, Data Processing for Rapid Prototyping, Integration of RE and RP for Layer-based Model Generation, Adaptive Slicing Approach for Cloud Data Modeling, Planar Polygon Curve Construction for a Layer, Determination of Adaptive Layer Thickness.

Re-Engineering in Automotive, Aerospace, Medical sectors: Legal Aspects of Re-Engineering: Copyright Law, Re-Engineering, Recent Case Law, Barriers to Adopting Re-Engineering. A discussion on a few benchmark case studies.

Learning Resources:

Text Books:

1. Product Design: Techniques in Reverse Engineering and New Product Development, K. Otto and K. Wood, Prentice Hall, 2001.
2. Reverse Engineering: An Industrial Perspective, Raja and Fernandes, Springer-Verlag 2008.

Reference Books:

1. Computer Aided Engineering Design, Anupam Saxena, Birendra Sahay, Springer, 2005.
2. Engineering Design and Rapid Prototyping, Ali K. Kamrani and Emad Abouel Nasr, Springer, 2010.
3. Advanced CAD Modeling Explicit, Parametric, Free-Form CAD and Re-engineering, Nikola Vukašinović and, Jože Duhovnik, Springer, 2019.

Online Resources:

1. https://www.polyga.com/reverse-engineering-101-scan-to-cad/
2. https://www.bft international.com/en/artikel/bft_Reverse_engineering_techniques_From_3D_scanning_to_the_CAD_file_in_the_3357131.html
3. https://physicaldigital.com/what-is-reverse-engineering/
4. https://all3dp.com/2/reverse-engineering-software-reverse-engineering-tools/

ME6547	COMPREHENSIVE VIVA – VOCE	Credits: 2

COMPREHENSIVE VIVA – VOCE OUTCOMES: At the end of the comprehensive viva-voce, the student shall be able to:

CO1	Comprehend the knowledge gained in the course work
CO2	Identify principles of working of automobile systems and controls
CO3	Demonstrate the ability in problem solving and to communicate effectively.

CO-PO MAPPING:

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

ME6549	DISSERTATION PART – A	Credits: 12

DISSERTATION OUTCOMES: At the end of the part – A of dissertation, the student shall be able to:

CO1	Identify a topic in advanced areas of additive manufacturing
CO2	Review literature to identify gaps and define objectives and scope of the work
CO3	Employ the ideas from literature and develop research methodology
CO4	Develop a model, experimental set-up and/or computational techniques necessary to meet the objectives.

M.Tech Dissertation Rubric Analysis:

Task	Description
I	Selection of Topic
II	Literature Survey
III	Defining the Objectives and Solution Methodology
IV	Performance of the Task
V	Dissertation Preparation
VI	Review (Presentation & Understanding)
VII	Viva-Voce
VIII	Publications /Possibility of publication

	ME 6549			
Task (% Weightage)	**CO1**	**CO2**	**CO3**	**CO4**
I (10)	X			
II (20)	X	X		
III (30)			X	
IV (40)				X

CO-PO MAPPING:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	1		3
CO2	3	2	3	1		3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3

ME6599	DISSERTATION PART – B	20 Credits

DISSERTATION OUTCOMES: At the end of the part – B of dissertation, the student shall be able to:

CO1	Identify the materials and methods for carrying out experiments/develop a code
CO2	Execute the research methodology with a concern for society, environment and ethics
CO3	Analyse, discuss and justify the results/trends and draw valid conclusions
CO4	Prepare the report as per recommended format and present the work orally adhering to stipulated time
CO5	Explore the possibility to publish/present a paper in peer reviewed journals/conference without plagiarism

Task – CO Mapping:

	ME 6599				
Task (% Weightage)	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
IV (40)	X	X			
V (20)				X	
VI (10)			X		
VII (20)				X	
VIII (10)					X

CO-PO MAPPING:

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

NOTE: Refer to the following link for the guidelines to prepare dissertation report:
https://www.nitw.ac.in/main/PGForms/NITW/