CURRICULUM & SYLLABI

M.Tech. AUTOMOBILE ENGINEERING

Effective from AY: 2024-25

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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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.

Vision and Mission of the Department
Mechanical Engineering

VISION

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

MISSION

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

Program: M.Tech. Automobile Engineering

Program Educational Objectives

PEO1	Apply concepts of engineering to analyze automotive systems.
PEO2	Develop innovative automotive technologies to address specific needs ofperformance, comfort, safety and eco-friendliness.
PEO3	Apply computational tools for comprehensive understanding of the complexsystems in automotive engineering.
PEO4	Communicate effectively and support constructively towards team work.
PEO5	Engage in lifelong learning for career and professional growth with ethicalconcern for society and the environment.

Program 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

Program: M.Tech. Automobile Engineering

Program Outcomes

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 Program Outcomes with Program 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

Curriculum
M.Tech. Automobile Engineering

I - Year, I – Semester

S. No.	Course Code		L - T - P	Credits
1	ME56001	Automotive Engineering	3 - 0 - 0	3
2	ME56003	Computational Methods in Automobile Engineering	3 - 0 - 0	3
3	ME56005	Prime Movers for Automobiles	3 - 0 - 0	3
4		Professional Elective - I	3 - 0 - 0	3
5		Professional Elective - II	3 - 0 - 0	3
6	ME56007	Automotive Engines Laboratory	0 - 1 - 2	2
7	ME56009	Geometric Modeling and Automation	0 - 1 - 2	2
			Total Credits	19

I - Year, II – Semester

S. No.	Course Code	Course Title	L - T - P	Credits
1	ME56002	Automotive Electronics	3 - 0 - 0	3
2	ME56004	Vehicle Dynamics	3 - 0 - 0	3
3		Professional Elective - III	3 - 0 - 0	3
4		Professional Elective - IV	3 - 0 - 0	3
5		Professional Elective - V	3 - 0 - 0	3
6	ME56006	Automotive Systems laboratory	0 - 1 - 2	2
7	ME56008	Engineering Analysis and SimulationLaboratory	0 - 1 - 2	2
8	ME56096	Minor Project	0 - 0 - 0	2
			Total Credits	21

M.Tech. Automobile Engineering – Course Structure

II- Year, I – Semester

S. No.	Course Code	Course Title	Credits
1	ME57089	Seminar & Technical Writing	2
2	ME57091	Summer Internship/ Research Experience (SIRE)	2
3	ME57093	Comprehensive Viva-Voce	2
4	ME57097	Dissertation: Part A	8
		Total	14

II - Year, II – Semester

S. No.	Course Code	Course Title	Credits
1	ME57098	Dissertation: Part B	12
		Total	12

Professional Elective Courses:

Professional Electives – I & II		
S.No.	**Code**	**Course Title**
1	ME56021	Vehicle Body & Safety Systems
2	ME56023	Vehicle Aerodynamics and Thermal Management
3	ME56025	Alternate Fuels and Emissions
4	ME56027	Engine Management Systems
5	ME16025	Renewable Sources of Energy
6	ME16027	Energy Systems and Management
7	ME26021	Precision Engineering
8	ME26041	Operation Management
9	ME36021	3D Printing Technologies
10	ME36033	Circular Economy
11	ME46021	Computer-Aided Geometric Design
12	ME46023	Analysis and Synthesis of Mechanisms
13	ME46027	Mathematical Methods in Engineering
14	ME46031	Automatic Control
15	ME46033	Systems Thinking for Engineering Applications

Professional Electives – III, IV & V		
S.No.	**Code**	**Course Title**
1	ME56022	Fuel Cell Technology
2	ME56024	Vehicle Testing and Instrumentation
3	ME56026	Hybrid Electric Vehicles
4	ME56028	Applied Finite Element Analysis
5	ME16024	Advanced Computational Fluid Dynamics
6	ME16032	Design of Heat Transfer Equipment
7	ME16040	Essentials of Entrepreneurship

8	ME16042	Combustion and Emission control
9	ME26028	Design and Analysis of Experiments
10	ME26030	Product Lifecycle Management
11	ME26040	Reliability engineering
12	ME36022	Supply Chain Management
13	ME36026	Project Management
14	ME36032	Artificial Intelligence and Machine Learning for Mechanical Systems
15	ME46022	AI/ML for Engineering Analysis
16	ME46024	Condition Monitoring and Fault Diagnostics
17	ME46028	Optimization Methods for Engineering Design
18	ME46032	Rotor dynamics
19	ME46034	Tribology in Design
20	ME46036	Characterization of Engineering Materials
21	ME46040	Noise, Vibrations & Harshness
22	ME46034	Design Thinking for Engineering Applications

Overall Credit Structure

Course Category	Credits
Program Core	23
Professional Elective	15
Minor Project	2
Seminar and Technical Writing	2
Summer Internship / Research Experience	2
Comprehensive Viva-Voce	2
Dissertation	20
Total Graded Credit Requirement	**66**

Syllabi

M.Tech. Automobile Engineering

1st Semester

ME56001 **3-0-0 (3)**

AUTOMOTIVE ENGINEERING

Prerequisites: **None**

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 ofAutomobiles, 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 **t**yre,tyre treads and tyre specifications

Learning Resources:

Text Books:

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

Reference Books:

1. Crouse and Anglin, Automotive Mechanism, , 9th Edition. Tata McGraw-Hill, 2017
2. Jack Erjavec, A Systems Approach to Automotive Technology, Cengage LearningPub2009.

ME56003 **3-0-0(3)**

COMPUTATIONAL METHODS IN AUTOMOBILEENGINEERING

Prerequisites: **None**

Course Outcomes:

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

CO1	Understand the Finite Element procedure to solve structural problems
CO2	Analyze the structural response for automotive structures.
CO3	Solve thermal and fluid flow problems using Finite Volume method
CO4	Analyze the coupled FE-FV 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, and Modified Galerkin Methods), Energy or Variational Methods.

Finite Element Formulation: Basic Finite Element Concepts, General finite element solution procedure, Concept of discretization, 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, Formulationof 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.

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 flowproblems, Discretization and solution of diffusion, convection-diffusion [Central differencing] equations through FVM, Pressure-Velocity Coupling [SIMPLE Algorithm], TDMA Algorithm, Coupled FE and FV procedure for Fluid-Structure Interaction problems and their applications in automotive systems.

Learning Resources:

Text Books:

1. Bhatti, M.A., Fundamental Finite Element Analysis and Applications: with Mathematica and Matlab Computations, Wiley, 2005.
2. Klaus-Jürgen Bathe, Finite Element Procedures in Engineering Analysis, Prentice-Hall,1982
3. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2007.
4. Patankar, Suhas. Numerical heat transfer and fluid flow. CRC press, 201

Reference Books:

1. Larry J. Segerlind, Applied Finite Element Analysis, 2nd Edition, Wiley.
2. J. Z. Zhu, OlgierdZienkiewicz, and Richard Taylor, The Finite Element Method: Its Basis and Fundamentals, 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/)

ME56005 **3-0-0(3)**

PRIME MOVERS FOR AUTOMOBILES

Prerequisites: **None**

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-NO_X) and Particulate Matter. Mechanism of formation of pollutants, Factors affecting pollutant formation. Brief treatmenton 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 Motorrun 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 toPEMFC and DMFCs.

Learning Resources:

Text Books:

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

Reference Books:

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

Online Resources:

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

ME56007 **0-1-2 (2)**

AUTOMOTIVE ENGINES LABORATORY

Prerequisites: **None**

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

ME56009 **0-1-2 (2)**

GEOMETRIC MODELLING AND AUTOMATION

Pre-Requisites: **None**

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 vehiclecomponents 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 desiredmodel.

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 andIntersection 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 andconstraints.
- 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 Kunwoo Lee, Principles of CAD/CAM/CAE, 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

2nd Semester

ME56002 **3-0-0(3)**

AUTOMOTIVE ELECTRONICS

Prerequisites: None

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, immersioncooling.

Learning Resources:

Text Books:

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

Reference Books:

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

Online Resources:

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

ME56004 **3-0-0(3)**

VEHICLE DYNAMICS

Prerequisites: **None**

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

Reference Books:

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

ME56006 **0-1-2 (2)**

AUTOMOTIVE SYSTEMS LABORATORY

Prerequisites: **None**

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

ME56008 **0-1-2 (2)**

ENGINEERING ANALYSIS AND SIMULATION LABORATORY

Prerequisites: **None**

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. H.K.Versteeg, W. Malalasekera, An introduction to computational fluid dynamics: the finite volume method, Pearson, 2008, 2nd edition

2. Tirupathi R. Chandrupatla, Ashok D.Belegundu, Introduction to Finite Elements in Engineering, 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)

ME56096 **0-0-0 (2)**

MINOR PROJECT

Prerequisites: **None**

Course Outcomes:

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

CO1	Apply engineering principles to real-world projects
CO2	Plan and monitor project tasks individually or as a team
CO3	Demonstrate practical experience in project execution
CO4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	
II	Study of Existing Systems and establishing clear objectives	
III	Planning of project and work distribution within the team	
IV	Proper Documentation and Technical Writing	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

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

3rd Semester

ME57089 **0-0-0 (2)**

SEMINAR AND TECHNICAL WRITING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	**Clarity on the topic**	
II	**List of lectures attended**	
III	**Report**	
IV	**Presentation**	
V	**Response to questions**	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	**X**		
II	**X**		
III		**X**	
IV			**X**
V			**X**

ME57091 **0-0-0 (2)**

SUMMER INTERNSHIP/ RESEARCH EXPERIENCE (SIRE)

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Every student has to undergo either a Summer Internship / EPICS / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The EPICS/research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Relevance of the area of work	
II	Performance of the Task	
III	**Crucial learnings from the work**	
IV	Report Preparation	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

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

ME57093 **0-0-0 (2)**

COMPREHENSIVE VIVA – VOCE

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

ME57097 **0-0-0 (8)**

DISSERTATION: PART-A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of Thermal Engineering.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	
II	Literature Survey	
III	Defining the Objectives and Solution Methodology	
IV	Performance of the Task	

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

4th Semester

ME57098 **0-0-0 (12)**

DISSERTATION: PART-B

Pre-Requisites: **Dissertation: Part-A**

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code.
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions.
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time.
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	Description	Weightages
IV	Performance of the Task	
V	Dissertation Preparation	
VI	Review (Presentation & Understanding)	
VII	Viva-Voce	
VIII	Publications /Possibility of publication	

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	X	X			
V				X	
VI			X		
VII				X	
VIII					X

Refer to the M.Tech. – “Refer to M.Tech. – Regulations for any further information regarding Mid-term review, End Sem evaluation, Template for report preparation and plagiarism”

Professional Electives – I &II

ME56021 **3-0-0(3)**

VEHICLE BODY & SAFETY SYSTEMS

Prerequisites: None

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	Identify different safety systems and their role in automobiles
CO5	Classify active, passive safety systems and collision warning systems

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. 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

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

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:ABS, Lighting system, Cruise control system, Tire pressure monitoring system

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, Airbag material and recent advancements

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 and Convenience System: Steering and mirror adjustment, central locking system, Rain sensor system, environment information system.

Learning Resources:

Text Books:

1. Powloski J, Vehicle Body Engineering, Business Books Ltd, 2000.
2. Lorenzo Morello, Automotive Body, Volume-I (component design), Springer, 2013
3. Ed May, "Automotive Mechanics Volume One" , McGraw Hill Publications, 2003
4. Ed May, "Automotive Mechanics Volume Two" , McGraw Hill Publications, 2003

Reference Books:

1. Bosch, “Automotive Handbook”, 8 th Edition, SAE publication, 2011.
2. Vehicle Service Manuals of reputed manufacturers
3. Jullian Happian-Smith ‘An Introduction to Modern Vehicle Design’ SAE, 2002

ME56023 **3-0-0(3)**

VEHICLE AERODYNAMICS AND THERMAL MANAGEMENT

Prerequisites: **Nil**

Course Outcomes:

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

CO1	Understand aerodynamic forces and moments of a ground vehicle.
CO2	Understand turbulent structures of vehicles and apply drag reduction methods.
CO3	Evaluate various battery thermal management solutions for EVs and HEVs
CO4	Apply principles of heat transfer and air-conditioning to develop mathematical models for HVAC in automobiles

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 to Vehicle Aerodynamics: Role of Aerodynamics in Vehicle design, Historical development of vehicle aerodynamics, Impact of aerodynamic drag on diverse shapes of ground vehicles, Significance of aerodynamic drag on fuel consumption and performance

Physical Principles of Aerodynamics: Derivation of conservation equations of mass and momentum, Boundary layer separation, Aerodynamic forces and moments for ahmed body, dead wake, longitudinal vortices, Pressure and viscous drag, drag reduction (active, passive and compound) methods

Modelling of turbulent structures around ground vehicles: Characteristic of turbulence, energy cascading, Reynolds-Averaged Navier Stokes Equations, Closure Problem, Boussinesq Eddy-viscosity approximation, Mixing length hypothesis, Algebraic models, One-equation and two-equation models, Application of various turbulence models to free shear flows and wall bounded flows, Near wall treatment, Direct Numerical Simulation (DNS), Large Eddy Simulation (LES) and related techniques.

Engine cooling and internal flow: Cooling requirements of an automobile, Engine cooling system circuit, fundamental modes of heat transfer, Heat Conduction in extended surfaces, Convection heat transfer in air-intakes and cooling ducts, Heat exchangers in vehicles.

Battery Thermal Management of Evs and HEVs: Importance of BTMS in EVs and HEVs, Air cooling, Liquid cooling, Phase Change Materials and Hybrid methods

Automotive Air-Conditioning and comfort control: Need of HVAC in automobiles, heat gain through vehicle body, Vapor compression refrigeration system, components of air-conditioning system (Compressor, TXV, Condenser, Evaporator, reciever/dryer) and their working.

Learning Resources:

Text Books:

1. Schuetz, Thomas Christian, Aerodynamics of road vehicles, SAE International, 5th Edition, 2015.
2. Joseph Katz, Automotive Aerodynamics, Wiley, 2016
3. Dincer, Ibrahim, Halil S. Hamut, and Nader Javani. Thermal management of electric vehicle battery systems. John Wiley & Sons, 2016.
4. Daly, Steven. Automotive air conditioning and climate control systems. Elsevier, 2011.

Reference Books:

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

ME56025 **3-0-0(3)**

ALTERNATE FUELS AND EMISSIONS

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 withpetroleum 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 inSI 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 ofhigher 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. M.K. Gajendra Babu , K.A. Subramanian Alternative Transportation Fuels: Utilisation in Combustion Engines, CRC Press ,2013

2. Akhilendra Pratap Singh, Yogesh C. Sharma,Nirendra N. Mustafi ,Avinash Kumar Agarwal, Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines, Springer 2020.

Reference Books:

1. Norbe Pundir B.P, Narosa Engine Emissions: Pollutant formation and advances in control Technology, 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

ME56027 **3-0-0(3)**

ENGINE MANAGEMENT SYSTEMS

Prerequisites: **None**

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

ME16025 **3-0-0(3)**

RENEWABLE SOURCES OF ENERGY

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 solarthermal systems for their utilization
CO3	Understand the principle of working of solar cells and their modernmanufacturing 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, geothermalenergy, 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 concentrationratio, 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. Thermodynamicanalysis 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. B.H.Khan, Non conventional Energy Resources, Tata McGraw Hill, New Delhi, 2017, 3rd edition
2. S.Rao and B.B.Parulekar, Energy Technology: Non-Conventional, Renewable and Conventional, Khanna Publishers, 2010, 1st Edition.

Reference Books:

1. S.P.Sukhatme and J.K.Nayak., Solar Energy-Principles of Thermal Collection and StorageTMH, 2010, 3rd edition (6 reprint).
2. J.A.Duffie and W.A.Beckman ., Solar Energy Thermal Processes, 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/)

ME16027 **3-0-0(3)**

ENERGY SYSTEMS AND MANAGEMENT

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 toimprove 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. De, B. K., Energy Management audit & Conservation ,Vrinda Publication, 2010, 2nd Edition.
2. Murphy, W. R., Energy Management,Elsevier , 2007, 1st Edition.

Reference Books:

1. Doty, S. and Truner, Energy Management Hand book 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/)

ME26021 **3-0-0(3)**

PRECISION ENGINEERING

Prerequisites: **NIL**

Course Outcomes:

CO1	Design and apply fits and tolerances for parts and assemblies according to ISO standards.
CO2	Apply selective assembly concept for quality and economic production.
CO3	Design and allocate tolerances using principles of dimensional chains for individual features of a part or assembly.
CO4	Evaluate the part and machine tool accuracies.

CO-PO Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3		2	2	2
CO2	3	3		2	2	2
CO3	3	3	3	2	2	2
CO4	3	3	3	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, Accuracy specification of parts and assemblies.

Precision Manufacturing: Micro machining processes-Diamond machining - Micro engraving - Micro replication techniques-Forming, Casting, Injection molding - Micro embossing. Methods of obtaining high quality surfaces, Lapping, Honing, Super finishing and Burnishing processes. Limitation of conventional manufacturing, Unconventional manufacturing methods - LBM, EBM, FIB, Micro electro discharge machining-photolithography-LIGA process- Silicon Micro Machining-Wet and dry etching-thin film deposition, applications – Smart Sensors, MEMS, Optical Components and Microfluidic devices.

Precision Metrology- In situ measurement- In process measurement of position of processing Point-Post process and online measurement of dimensional features- Mechanical measuring systems-Optical Measuring Systems- Optical Interferometry, Laser Scanning, White Light Interferometry Confocal Microscopy, Electron beam measuring Systems-Scanning Tunnelling-Atomic Force Microscope and X-Ray Computed Tomography. Surface Metrology-Surface Roughness and Measurement

Nano precision technology: Fundamentals of nanotechnology, Nano physical processing of atomic-bit-units Nano chemical and electrochemical atomic-bit processing. –Nano-Grating systems –Nano lithography, Electron beam lithography –Mirror grinding of ceramics, Focused Ion Beam (FIB) Milling, Atomic Layer Deposition (ALD), Nano processing of materials for super high-density ICs-Nano-mechanical parts, Nano machines-NEMS, Applications- Nanoelectronics, Nanocomposites and nano coatings.

Geometric Dimensioning and Tolerancing: 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 dimensional chain or tolerance stack. Dimensioning of stepped shaft and holes assigning tolerances on the constituent dimensions. Tolerance zone conversions-surfaces, Datum - Datum feature of representation-form controls, Logical approach to tolerancing-datum systems, Geometrical tolerances.

Learning Resources:

Text Books:

1. R.L.Murty, ”Precision Engineering in Manufacturing”, New Age International Publishers, 1996.
2. James, D. and Meadow, S., “Geometric Dimensioning and Tolerancing”, Marcel Dekker Inc.,1995.

Reference Books:

1. V.Kovan, "Fundamentals of Process Engineering", Foreign Languages Publishing House, Moscow, 1975
2. J.L.Gadjala, "Dimensional control in Precision Manufacturing", McGraw Hill Publishers.
3. Norio Tanigichi “Nano Technology”, oxford university press, 2003.
4. Venkatesh, V.C. and Sudin, I., “Precision Engineering”, Tata McGraw Hill Co., NewDelhi, 2007.
5. Liangchi Zhang, “Precision Machining of Advanced Materials”, Trans Tech Publications Ltd., Switzerland, 1st Edition, 2001.
6. X. Jane Jiang, Paul J. Scott, “Advanced Metrology: Freeform Surfaces”, Academic Press Inc, April 2020.

ME26041 **3-0-0(3)**

OPERATION MANAGEMENT

Prerequisites: NIL

Course Outcomes:

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

CO1	Design of production planning and control systems encompassing competitivepriorities 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 byconsidering 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.

Learning Resources:

Text Books:

1. Joseph G Monks, Operation Management, McGrew Hill Publication, International Edition-1987.

2. Pannerselvam R., Production and Operation Management", PHI publications, 2nd edition

3. TPS Yasuhiro, An Introductory book on lean System, Modern.

Reference Books:

1. Chary S. N, Production and Operation Management, TataMcGrew Hill 5th edition 2019

2. Everett E. Adams, Ronald J. Ebert, Production and Operations Management, Prentice Hall of India Publications, 5th Edition.

3. Buffia, Modern Production/Operations Management, Wiely India Ltd 8th Edition.

ME36021 **3-0-0 (3)**

3D PRINTING TECHNOLOGIES

Prerequisites: **NIL**

Course Outcomes:

CO1	Develop preprocess data for the 3D Printing
CO2	Identify properties of 3DP materials and their influence on final part quality
CO3	Describe the working principles of each 3D Printing technology
CO4	Apply suitable 3D Printing technology for any given industrial application
CO5	Select the postprocessing and testing method for the given application

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Computer Aided Design (CAD) and Preprocessing Data for 3D Printing: Introduction to Geometric Modelling. Modelling of Synthetic Curves like Hermite, Bezier and B-spline; Parametric Representation of Freeform Surfaces and Solids. CAD Data Exchange Formats, Input File Sources and Characteristics, 3D Printing Data File Formats and Software, STL File Errors and Manipulation, 3D Printing Process Chain, Part Orientation and Support Generation, Model Slicing and Contour Data Organisation, Hatching Strategies, 3D Printing Toolpaths Generation and Process Plan, Build Preparation and 3D Printing Process Simulation.

3D Printing Materials and Characterisation: Nature of Thermoplastics and Thermosetting Polymers, Properties of Metal and Ceramics. *3DP Liquid Materials:* Rheology and Wetting Behaviour. *3DP Solid Materials:* Filament Diameter Consistency, Density, Porosity, Moisture Content, Thermal Properties, Microstructure of Composite Filament, Mechanical Properties of Filament. *3DP Powder Materials:* Powder Size Measurements, Morphology, Chemical Composition, Flow Characteristics, Density, Energy Absorption Characteristics of Powder.

3D Printing Processes: Classification of 3D Printing Processes. Description, Process Parameters, Material Selection and Characterisation, Applications, Strengths and Weaknesses of Vat Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Sheet Lamination, Powder Bed Fusion and Directed Energy Deposition Processes; *Other Processes:* Aerosol Printing and Bio-plotter. *Construction of DIY Printers:* Motion System, Frame/Chassis, Print Bed, Extruder, Electronics.

3D Printing Applications: An Overview of 3D Printing Applications, *Aerospace:* Aerospace Materials and their Requirements, Qualification and Certification of Parts, Aerospace Case Studies. *Medical:* Medical Scanning Technologies, Biomaterials, Planning and Simulation of Complex Surgeries, Design and Fabrication of Customized Implants, Medical Case Studies. *Automobile:* Prototyping, Jigs and

Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. *Other Applications of 3DP:* Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

Postprocessing and Testing of 3DP Parts: Need for Postprocessing in 3DP, *Surface Treatment Methods:* Subtractive Machining Methods, Thermal-based Methods, Abrasive-based Methods, Chemical Methods. *Surface Protection, Functionalization, and Decorative Methods.* Heat Treatment and Aging. Establish a Relationship between Processing Parameters, Resulting Microstructure, Mechanical Properties, Fatigue, Creep and Corrosion Resistance of 3DP Parts. *Testing of 3DP Parts:* Metrology Measurement Methods, Porosity and Density, Dimensions, Mechanical Measurement Methods, NDT Methods of 3DP Parts, 3DP Safety, 3DP Standards.

Learning Resources:

Text Books:

1. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, Tata McGrawHill, 2008.
2. Damir Godec, Joamin Gonzalez-Gutierrez, Axel Nordin, Eujin Pei, Julia Urena Alcazar, A Guide to Additive Manufacturing, Springer, 2022.
3. Ian Gibson, David Rosen, Brent Stucker, and Mahyar Khorasani, Additive Manufacturing Technologies, Springer, 2021,3rd Edition.
4. Diegel, Olaf, Axel Nordin,Damien Motte, A Practical Guide to Design for Additive Manufacturing, Springer, 2020.
5. Zafar Alam Faiz Iqbal, Dilshad Ahmad Khan, Post-processing Techniques for Additive Manufacturing, CRC Press, 2024.

References Books:

1. Michael E.Mortenson, Geometric Modeling, McGrawHill, 2013.
2. Patri K.Venuvinod, Weiyin Ma, Rapid Prototyping: Laser-based and Other Technologies, Springer, 2004.
3. Sanjay Joshi, Richard P. Martukanitz, Abdalla R. Nassar, Pan Michaleris Additive Manufacturing with Metals: Design, Processes, Materials, Quality Assurance, and Applications, Springer, 2023.
4. L.Lu, J. Y. H. Fuh and Y.S.Wong, Laser-Induced Materials and Processes for Rapid Prototyping,Springer, 2001.
5. Chua Chee Kai, Leong Kah Fai, Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, World Scientific, 2019,5th Edition.
6. Gurminder Singh, Ranvijay Kumar, Kamalpreet Sandhu, Eujin Pei, and Sunpreet Singh, Handbook of Post-Processing in Additive Manufacturing Requirements Theories and Methods, CRC Press, 2024.

ME36033 **3-0-0 (3)**

CIRCULAR ECONOMY

Pre-Requisites: **None**

Course Outcomes:

CO1	Apply the concept of circular economy to environmental engineering problems
CO2	Understand the concept of circularity and conduct relevant research
CO3	Use the principles of circularity for application to sustainable development
CO4	Apply complexity aspects of circular economy for creating circular business models

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Linear Economy and its emergence, Economic and Ecological disadvantages of linear economy, Replacing Linear economy by Circular Economy, Development of Concept of Circular Economy, A differential - Linear Vs Circular Economy

Characteristics of Circular Economy: Material recovery, Waste Reduction, reducing negative externalities, Explaining Butterfly diagram, Concept of Loops

Circular design, innovation and Assessment: Zero waste: Waste Management in context of Circular Economy, Circular design, Research and innovation, LCA, Circular Business Models

Case Studies: Business models, Solid Waste Management / Wastewater, Plastics: A case study, EPR: polluters pay principle, Industrial symbiosis/ ECOparks

Legal and policy framework: Role of governments and networks, Sharing best practices, Universal circular economy policy goals, India and CE strategy, ESG

Learning Resources:

Text Books:

1. Walter R Stahel, The Circular Economy A User's Guide, Routledge, 2019, 1st Edition
2. Shalini Goyal Bhalla, Circular Economy: (Re) Emerging Movement, Invincible Publisher

Reference Books:

1. Peter Lacy, Jessica Long, Wesley Spindler, The Circular Economy Handbook: Realizing The Circular Advantage, Palgrave Macmillan UK
2. Peter Lacy, Jakob Rutqvist, Waste to Wealth: The Circular Economy Advantage, Palgrave Macmillan

Online references

1. https://www.coursera.org/learn/circular-economy
2. https://www.edx.org/course/circular-economy-an-introduction
3. https://www.coursera.org/learn/sustainable-digital-innovation
4. https://online-learning.harvard.edu/course/introduction-circular-economy?delta=0
5. https://www.oecd.org/cfe/regionaldevelopment/Ekins-2019-Circular-Economy-WhatWhy-How-Where.pdf
6. https://ic-ce.com/product/principles-of-circular-economy/
7. https://ic-ce.com/product/circular-business-management/
8. https://ic-ce.com/product/bootcamp/
9. http://ic-ce.com/journal-on-circular-economy/

ME46021 **3-0-0 (3)**

COMPUTER-AIDED GEOMETRIC DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply geometric transformations and projection methods in CAD
CO-2	Develop geometric models to represent curves
CO-3	Design surface and solid models for engineering design
CO-4	Apply mesh generation techniques for engineering analysis

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

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:

Text Books:

1. Michael E. Mortenson, Geometric Modeling, Tata McGraw Hill, 2013.
2. Saxena and B. Sahay, Computer-Aided Engineering Design, Anamaya Publishers, New Delhi, 2005.

Reference Books:

1. Rogers, David F.Morgan, An introduction to NURBS: with historical perspective, Kaufmann Publishers, USA, 2001.
2. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.
3. Kunwoo Lee, Principles of CAD/CAM/CAE systems, Addison-Wesley, 1999.

ME46023 **3-0-0 (3)**

ANALYSIS AND SYNTHESIS OF MECHANISMS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand basic mechanisms and machines and formulate the design problem.
CO-2	Develop analytical equations for relative position, velocity and acceleration of all moving links.
CO-3	Analyze Simple and Complex mechanisms.
CO-4	Apply the knowledge of Kinematic theories to practical problems of mechanism design and synthesis.
CO-5	Design higher pair kinematic linkages for a given application.

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

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

Kinematic Analysis: Review on graphical methods**,** algebraic position analysis; loop closure equations; the position of any point on a linkage; transmission angles and toggle positions; position-based synthesis of planar mechanisms. Velocity and acceleration analysis of Four-link and slider crank mechanisms using vector loop equations, coriolis component

Synthesis: Function generation, path generation, motion generation, Graphical Method**-** two-position and three-position synthesis of planar mechanisms, synthesis of quick return mechanisms, coupler curves, and exact and approximate straight-line mechanisms. Analytical linkage synthesis- two and three-position synthesis using vector loop equation, precision points, comparison of analytical and graphical synthesis methods.

Design of CAMS: Terminology and classification, double dwell cam design, svaj diagrams, combined functions, SCCA family, Polynomial Functions.

Robot Kinematics: Introduction to spatial descriptions and transformations, forward and inverse kinematics of manipulators

Learning Resources:

Text Books:

1. R L Norton, Kinematics and Dynamics of Machinery, McGraw Hill reprint 2016, 2nd Edition.

Reference Books:

1. John J. Craig, Introduction to robotics-Mechanisms and control, Pearson Education, Inc., 2005, 3rd edition,
2. Sandor and Erdman, Advanced Mechanism Design: Analysis and Synthesis, Vol II,PHI, New Delhi, 2010.

ME46027 **3-0-0 (3)**

MATHEMATICAL METHODS IN ENGINEERING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Extend the methods of Applied Linear Algebra to engineering design problems
CO-2	Solve problems involving Nonlinear Optimization in engineering
CO-3	Simulate engineering systems using Numerical Methods.
CO-4	Model physical systems using Differential Equations

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Solution of Systems of Linear Equations: Introduction, Basic Ideas of Applied Linear Algebra, Systems of Linear Equations, Square, Non-Singular Systems, ILL-Conditioned and ILL-Posed Systems.

The Algebraic Eigenvalue Problem: The Algebraic Eigenvalue Problem, Canonical Forms, Symmetric Matrices, Methods of Plane Rotations, Householder Method, Tridiagonal Matrices, QR Decomposition, General Matrices.

Selected Topics in Linear Algebra and Calculus: Singular Value Decomposition, Vector Space: Concepts, Multivariate Calculus, Vector Calculus in Geometry, Vector Calculus in Physics.

An Introductory Outline of Optimization Techniques: Solution of Equations, Introduction to Optimization, Multivariate Optimization, Constrained Optimization: Optimality Criteria, Constrained Optimization: Further Issues.

Selected Topics in Numerical Analysis: Interpolation, Regression, Numerical Integration, Numerical Solution of ODE's as IVP Boundary Value Problems, Question of Stability in IVP Solution, Stiff Differential Equations, Existence and Uniqueness Theory.

Ordinary Differential Equations: Theory of First Order ODE's, Linear Second Order ODE's, Methods of Linear ODE's, ODE Systems, Stability of Dynamic Systems.

Application of ODE's in Approximation Theory: Series Solutions and Special Functions, Sturm-Liouville Theory, Approximation Theory and Fourier Series, Fourier Integral to Fourier Transform, Minimax Approximation.

Overviews: PDE's, Complex Analysis and Variational Calculus: Separation of Variables in PDE's, Hyperbolic Equations, Parabolic and Elliptic Equations, Membrane Equation, Analytic Functions, Integration of Complex Functions, Singularities and Residues, Calculus of Variations.

Learning Resources:

Text Books:

1. B. Dasgupta, Applied Mathematical Methods, Pearson Education, 2006.
2. E. Kreyszig , Advanced Engineering Mathematics, Wiley, 2010.

Reference Books:

1. M. T. Heath, Scientific Computing, McGraw-Hill Education, 2001.

ME46033 **2-0-2 (3)**

Systems Thinking for Engineering Applications

Pre-Requisites: None — Basic engineering background is sufficient.

Course Outcomes:

CO1	Understand and explain the fundamental concepts of systems thinking — system boundaries, stocks, flows, feedback loops, delays, and non-linearity — in the context of mechanical engineering systems.
CO2	Construct and interpret Causal Loop Diagrams (CLDs) and Stock-and-Flow (SF) models to represent the dynamic behaviour of thermal, manufacturing, design, and automobile engineering systems.
CO3	Analyse system archetypes, feedback structures, and systemic failure modes to diagnose leverage points and unintended consequences in complex engineering problems.
CO4	Evaluate dynamic system behaviour including oscillations, overshoot, collapse, and growth using qualitative and introductory quantitative system dynamics modelling tools.
CO5	Design systemic interventions for complex real-world engineering problems by integrating systems thinking principles with sustainability, resilience, and sociotechnical considerations.

CO-PO Correlation Matrix

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Foundations of Systems Thinking: Why reductionist thinking fails for complex engineering problems; what is a system; system boundary, elements, interconnections, and purpose; open vs closed systems; stocks and flows — the building blocks of dynamic systems; Little's Law; feedback loops — reinforcing and balancing; delays; non-linearity and limits to growth; system traps; mental models and bounded rationality; case studies.

System Archetypes and Feedback Dynamics: Introduction to system archetypes — eight classic patterns (Senge, 1990); Archetypes 1–4: Limits to Growth, Shifting the Burden, Fixes that Fail, Tragedy of the Commons; Archetypes 5–8: Escalation, Eroding Goals, Growth and Underinvestment, Accidental Adversaries; oscillation and instability in feedback systems; archetype case studies across ME domains.

Causal Loop Diagrams and Stock-Flow Modelling: CLD notation, polarity conventions, loop identification and labelling; CLD construction; Systems Mapping methods — participatory causal mapping; comparing and combining CLDs with other causal mapping approaches (Barbrook-Johnson and Penn, 2022); Stock-and-Flow diagram notation; constructing SF models; rate and level equations; introduction to Vensim PLE software; simulation of reference mode behaviour; model validation and testing; sensitivity analysis; group modelling exercise.

Systems Thinking in Mechanical Engineering Domains: Systems Thinking in Thermal Engineering — CLD and case study: combined cycle power plant; Systems Thinking in Manufacturing Engineering — production system as a stock-flow network; Systems Thinking in Design Engineering — product development rework loops and schedule dynamics; Systems Thinking in Automobile Engineering — vehicle programme delay; cross-domain integration.

Complexity, Leverage, Sustainability and Systemic Design: Leverage points — Meadows' 12 places to intervene in a system; Complex Adaptive Systems; resilience and sustainability through a systems lens; Sociotechnical systems and transition dynamics; systemic design methodology; capstone project reviews — systems model and intervention recommendation presentations.

Experiential Practice and Capstone Project Work:

Student teams construct a complete Causal Loop Diagram and Stock-and-Flow model for a real engineering problem from their specialisation, identify leverage points using Meadows' hierarchy, and present a systems-aware intervention recommendation with sustainability implications. Vensim PLE software is used for simulation.

Learning Resources:

Text Books :

1. Donella H. Meadows (Ed. Diana Wright), Thinking in Systems: A Primer, Chelsea Green Publishing, 2008.

2. John D. Sterman, Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw-Hill/Irwin, 2000.

Reference Books:

1. Peter M. Senge, The Fifth Discipline: The Art and Practice of the Learning Organization, Updated Edition, Doubleday/Currency, New York, 2006.

2. Pete Barbrook-Johnson and Alexandra S. Penn, Systems Mapping: How to Build and Use Causal Models of Systems, Palgrave Macmillan, 2022. [Open Access — full PDF freely available at link.springer.com]

3. Brian C. Dangerfield (Ed.), System Dynamics: Theory and Applications, Springer, New York, 2020.

4. David Peter Stroh, Systems Thinking for Social Change: A Practical Guide to Solving Complex Problems, Chelsea Green Publishing, 2015.

Professional Electives – III, IV & V

ME56022 **3-0-0(3)**

FUEL CELL TECHNOLOGY

Pre-Requisites: **None**

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

Reference Books:

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

ME56024 **3-0-0(3)**

VEHICLE TESTING AND INSTRUMENTATION

Prerequisites: **None**

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 inengine 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-Descriptionof 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. Richard D. Atkins, An Introduction to Engine Testing and Development, SAE International2009.
2. S.P. Venkateshan,Mechanical Measurements, ANE/Athena Books, 2015,2nd Ed.

Reference Books:

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

ME56026 **3-0-0(3)**

HYBRID ELECTRIC VEHICLES

Prerequisites: **None**

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

Reference Books:

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

Online Resources:

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

ME56028 **3-0-0(3)**

APPLIED FINITE ELEMENT ANALYSIS

Prerequisites: **None**

Course Outcomes:

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

CO1	Apply continuum and structural elements to formulate, integrate and solve elastic problems.
CO2	Analyse different plasticity models to approximate the behaviour of different materials.
CO3	Demonstrate commercial finite element analysis packages to carry out linear and nonlinear analysis of structures
CO4	Evaluate material and geometric nonlinearities to assess the difficulties experienced in finite element solutions.

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: Need of Approximation, Why FEA?, Finite Element Applications in Engineering, FEA with ANSYS Workbench, A Brief History of FEA, A General Procedure for FEA for a Spring System, One Spring Element, Spring System, Bars and Trusses, Beams and Frames, Assembly of Element Equations: Direct Approach, Assembly of Element Equations: Energy Approach, Boundary and Load Conditions, Solution Verification, Overview of Commercial FEA Packages

Two-Dimensional Elasticity: Introduction, Review of 2-D Elasticity Theory Plane Stress, Plane Strain Stress–Strain (Constitutive) Equations, Strain and Displacement Relations, Equilibrium Equations, Boundary Conditions, Exact Elasticity Solution, Modelling of 2-D Elasticity Problems, Formulation of the Plane Stress/Strain Element, A General Formula for the Stiffness Matrix, Constant Strain Triangle (CST), Quadratic Triangular Element (LST or T6), Linear Quadrilateral Element (Q4), Quadratic Quadrilateral Element (Q8), Transformation of Loads, Stress Calculation [The von Misses Stress and Averaged Stresses], General Comments on the 2-D Elements, Case Study with Commercial FEA Package

Modelling and Solution Techniques: Introduction, Substructures (Super elements), Equation Solving [Direct Methods (Gauss Elimination), Iterative Methods], An Example on Gauss Elimination, An Example on Iterative Method, Nature of Finite Element Solutions, Convergence of FEA Solutions, Adaptivity (h-, p-, and hp-Methods), Case Study with Commercial FEA Package

Plate and Shell Analyses: Introduction, Review of Plate Theory, Force and Stress Relations in Plates, Thin Plate Theory (Kirchhoff Plate Theory), Thick Plate Theory (Mindlin Plate Theory), Shell Theory, Modelling of Plates and Shells, Formulation of the Plate and Shell Elements, Kirchhoff Plate Elements, Mindlin Plate Elements, Discrete Kirchhoff Elements, Flat Shell Elements, Curved Shell Elements, Case Studies with Commercial FEA Package

Three-Dimensional Elasticity: Review of Theory of Elasticity, Stress–Strain Relation, Displacement, Strain–Displacement Relation, Equilibrium Equations, Boundary Conditions and Stress Analysis, Modeling of 3-D Elastic Structures, Mesh Discretization, Boundary Conditions: Supports, Boundary

Conditions: Loads, Assembly Analysis: Contacts, Formulation of Solid Elements, Typical Solid Element Types, Formulation of a Linear Hexahedral Element Type, Treatment of Distributed Loads, Case Studies with Commercial FEA Package

Structural Vibration and Dynamics: Review of Basic Equations, A Single DOF System, A Multi-DOF System, Mass Matrices, Damping, Formulation for Modal Analysis, Modal Equations, Formulation for Frequency Response Analysis [Modal Method and Direct Method], Formulation for Transient Response Analysis [Direct Methods (Direct Integration Methods) and Modal Method], Modelling Examples [Modal Analysis, Frequency Response Analysis, Transient Response Analysis], Cautions in Dynamic Analysis, Case Studies with Commercial FEA Package

Thermal Analysis: Review of Basic Equations, Finite Element Formulation for Heat Conduction, Modelling of Thermal Problems [Thermal Analysis and Thermal Stress Analysis], Thermal Stress Analysis [1-D Case, 2-D Cases and 3-D Case], Case Studies with Commercial FEA Package

Introduction to Fluid Analysis: Review of Basic Equations, Describing Fluid Motion [Types of Fluid Flow and Navier–Stokes Equations], Modelling of Fluid Flow [Fluid Domain, Meshing, Boundary Conditions, Solution Visualization], Case Studies with Commercial FEA Package

Design Optimization: Need of Optimization for engineering designs, Topology Optimization, Parametric Optimization, Design Space Exploration for Parametric Optimization, Design of Experiments, Response Surface Optimization, Case Studies with Commercial FEA Package

Failure Analysis: Introduction, Static Failure, Ductile Failure, Maximum Shear Stress Theory (Tresca Criterion), Distortion Energy Theory (von Mises Criterion), Brittle Failure, Maximum Normal Stress Theory, Mohr–Coulomb Theory, Fatigue Failure, Soderberg Failure Criterion, Goodman Failure Criterion, Gerber Failure Criterion, Buckling Failure, Case Studies with Commercial FEA Package

Crash Analysis: Importance of Structural Crashworthiness, Transient Dynamics Solution Methodology, Increasing the speed of Explicit Methods for Quasi Static Simulation, Comparison of Explicit vs. Implicit Methods, Issues in Contact Analysis, Full Dynamic or Impact vs. Quasi Static Simulations, Effect of Process and Residual Stress on Crash Analysis, Application of Crash Worthiness Simulations in automotive engineering, Case Studies with Commercial FEA Package

NVH Analysis: Introduction to NVH Concepts, Frequency Range of FE Dynamic Analysis, FEA for Acoustics, Vibration and Noise Control, Case Studies with Commercial FEA Package

Learning Resources:

Text Books:

1. Saeed Moaveni, Finite Element Analysis Theory And Application With ANSYS, Pearson India; 3rd edition (1 January 2011)
2. Xiaolin Chen, Finite Element Modeling and Simulation with ANSYS Workbench, Second Edition
3. G. Ramamurty, Applied Finite Element Analysis, 2010, I.K International Publishing House Pvt. Ltd., India

Reference Books:

1. Larry J. Segerlind, Applied finite element analysis, Second Edition, John Wiley & Sons Inc., 1994
2. Frank L. Stasa, Holt, Applied finite element analysis for engineers, Rinehart & Winston of Canada Ltd

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 Open Courseware (Link: https://ocw.mit.edu/resources/ res-2-002-finite-element-procedures-for-solids-and-structures-spring-2010/)

ME16024 **3-0-0(3)**

ADVANCED COMPUTATIONAL FLUID DYNAMICS

Prerequisites: **None**

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

Reference Books:

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

ME16032 **3-0-0(3)**

DESIGN OF HEAT TRANSFER EQUIPMENT

Prerequisites: **None**

Course Outcomes:

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

CO1	Understand the physics and the mathematical treatment of typical heatexchangers.
CO2	Apply LMTD and Effectiveness - NTU methods in the design of heatexchangers
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 – Poolboiling 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, Numericalproblems.

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

Reference Books:

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

Online Resources:

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

ME16040 **3-0-0(3)**

ESSENTIALS OF ENTREPRENEURSHIP

Prerequisites: **None**

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

Reference Books:

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

ME16042 **3-0-0(3)**

COMBUSTION AND EMISSION CONTROL

Prerequisites: **None**

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 GasTurbines.
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 legislationstandards.

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

Reference Books:

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

Online Resources:

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

ME26028 **3-0-0(3)**

DESIGN AND ANALYSIS OF EXPERIMENTS

Prerequisites: **None**

Course Outcomes:

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

CO1	Identify objectives and key factors in designing experiments.
CO2	Develop appropriate experimental design to conduct experiments.
CO3	Analyse experimental data and draw valid conclusions.
CO4	Develop empirical models using experimental data to optimize process parameters.
CO5	Design robust products and processes using parameter design approach.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

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.

Text Books:

1. Montgomery D. C., Design and Analysis of Experiments, John Wiley & Sons, 2010, 7thEdition.
2. Ross P. J., Taguchi Techniques for Quality Engineering, McGraw-Hill, NY, 2008.
3. Madhav S. Phadke, Quality Engineering using Robust Design, Prentice Hall, 1989

Reference Books:

1. Dukkipati, R V and Pradip K Ray,Product and Process Design for Quality, Economy and Reliability, New Age International,2010, 1st Edn.

Online Resources:

1. http://reliawiki.org/index.php/Experiment_Design_and_Analysis_Reference
2. https://ieeexplore.ieee.org/abstract/document/6771276
3. https://link.springer.com/chapter/10.1007/978-1-4684-1472-1_1

ME26030 **3-0-0(3)**

PRODUCT LIFE CYCLE MANAGEMENT

Prerequisites: None

Course Outcomes:

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

CO1	Understand product data, information, structures and PLM concepts.
CO2	Apply PLM systems in organization verticals including production, after sales, sales and marketing, and subcontracting.
CO3	Measure benefits of PLM implementation in daily operations, material costs, productivity of labour and quality costs.
CO4	Apply PLM concepts for service industry and E-Business.
CO5	Recognize tools and standards in PLM.
CO6	Propose implementation methods to deploy a PLM system in a global company

Course Articulation Matrix:

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

Syllabus:

Fundamentals of PLM: Product data or Product information, Product lifecycle management concept, The P L and M of PLM – PLM Paradigm – The PLM Environment – Issues in traditional environment – Product Data Issues – Product Pains - Opportunities

Business Processes in the PLM Environment – Introduction – Process reality in a typical company – Business process activities in a PLM initiative **-**Business process improvement approaches - Configuration Management – Engineering Change Management

Product Structures: Standardized product data and materials data model, KPIs for product data – Generic issues with product data – Product data activities in the PLM initiative.

PLM service information model: Categorizing services , Rational for building service products, How to make a service more like a tangible product?, Making items out of product functions, PLM challenges in service business, An IT-service provider and a customer-specifically variable product.

Integration of the PLM system with other applications: Different ways to integrate PLM systems, Goal of integrating PLM, SCM and ERP – Digital Transformation of PLM -IoT in Manufacturing – Convergence of PLM with IIoT.

Implementing end to end business process management: Product lifecycle management as a business strategy tool, Product lifecycle management as an enabler of cooperation between

companies, Contents of collaboration, Successful cooperation, Tools of collaboration, From changes in the business environment to product strategy, Business Benefits of PLM.

PLM applications in process and product industries examples: Case 1: Electronics manufacturer, Case 2: An engineering product, Case 3: Capital goods manufacturer and customer-specifically variable product, Case 4: An IT-service provider and a customer-specifically variable product.

Case Studies with Siemens Teamcenter PLM or similar softwares.

Text Books:

1. John Stark, Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation (Decision Engineering), Springer, 2020.
2. Antti Saaksvuori, Anselmi Immonen , Product Lifecycle Management, Third Edition, Springer, 2008.
3. *SOA approach to Enterprise Integration for Product Lifecycle*, IBM Red books, 2011.
4. Udhayan Elongovan, Product Life Cycle Management (PLM), A Digital Journey using Industrial Internet of Things, CRC Press, 2020

Reference Books:

1. John Stark, Product Lifecycle Management (Volume 2): The Devil is in the Details, Springer, 2016.
2. John Stark, Product Lifecycle Management (Volume 4): The Case Studies (Decision Engineering), Springer, 2016.
3. Anthony A. Atkinson, Management Accounting, 6th Edition, Prentice Hall, Inc., 2012
4. Cecil B. Bozarth, Robert B. Handfield, Introduction to Operations and Supply Chain Management, 5th Edition, Pearson, 2019.

ME26040 **3-0-0(3)**

RELIABILITY ENGINEERING

Prerequisites: **None**

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	3	2	
CO4	3	2	2	2		
CO5	2	2	2	2	2	

Detailed Syllabus:

Introduction: Probabilistic reliability, failures and failure modes, repairable and nonrepairable 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. Ebeling CE, *An Introduction to Reliability and Maintainability Engineering*, TMH, New Delhi, 2004.

2. O'Connor P and Kleymer A, *Practical Reliability Engineering*, Wiley, 2012.

ME36022 **3-0-0 (3)**

SUPPLY CHAIN MANAGEMENT

Prerequisites: None

Course Outcomes:

CO1	Understand the decision phases and apply competitive and supply chain strategies.
CO2	Understand drivers of supply chain performance.
CO3	Analyze factors influencing network design.
CO4	Analyze the role of forecasting in a supply chain
CO5	Understand the role of aggregate planning, inventory, IT and coordination in a supp chain.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Strategic Framework: 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.

Supply Chain Drivers and Metrics: Drivers of supply chain performance, Framework for structuring Drivers, Obstacles to achieving strategic fit.

Designing Supply Chain Network: Factors influencing Distribution Network Design, Design options for a Distribution network, E-Business and Distribution network, Framework for Network Design Decisions, Models for Facility Location and Capacity Allocation.

Forecasting in SC: Role of forecasting in a supply chain, Components of a forecast and forecasting methods, Risk management in forecasting.

Aggregate Planning and Inventories in SC: Aggregate planning problem in SC, Aggregate Planning Strategies, Planning Supply and Demand in a SC, Managing uncertainty in a SC: Safety Inventory.

Coordination in SC: Modes of Transportation and their performance characteristics, Supply Chain IT framework, Coordination in a SC and Bullwhip Effect.

Learning Resources:

Text Books:

1. Sunil Chopra and Peter Meindl, Supply Chain Management - Strategy, Planning and Operation, Pearson Education Asia, 2010, 4th Edition.
2. David Simchi-Levi, PhilpKamintry and Edith Simchy Levy,Designing and Managing the Supply Chain - Concepts Strategies and Case Studies, Tata-McGraw Hill, 2000, 2nd Edition.
3. John J Coyle, Managing Supply Chains A Logistics Approach', Cengage Learning, 2013, 9th Edition.
4. Jeremy F Shapiro, Modeling the Supply Chain', Cengage Learning, 2007, 2nd Edition.

Online Resources:

1. https://scm.mit.edu/

ME36026 **3-0-0 (3)**

PROJECT MANAGEMENT

Prerequisites: **None**

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, ProjectLife Cycle.

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

Financial Analysis: Financial Estimates and Projections, Investment Criteria, Financing ofProjects.

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, Schedulingwhen resources are limited.

Project Risk Management: Scope Management, Work Breakdown Structure, EarnedValue Management, Project Risk Management.

Text Books:

1. Prasanna Chandra, A Planning Analysis, Tata McGraw Hill,New Delhi, 2009, 4th Edition.
2. Cleland, Gray and Laudon, Project Management, Tata McGraw Hill,New Delhi, 2007, 3rd Edition.
3. Jack R. Meredith and Samuel J., Jr.Mantel, Project Management - A Managerial Approach, John Wiley, 2011, 6th Edition.

Reference Books:

1. Eliyahu M Goldratt, The Critical Chain, Business novel, 1997
2. A guide to the Project Management Body of Knowledge, ProjectManagement Institute, 2008, 4th Edition.

Online Resources:

1. https://www.pmi.org/
2. https://www.pma-india.org/pma-cert/

ME36032 **3-0-0 (3)**

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR MECHANICAL SYSTEMS

Prerequisites: **None**

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 Industry4.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 experimentalanalysis

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-PhysicalSystems 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, Design of Experiments, 2017. John Wiley and Sons, Inc.

ME46022 **3-0-0 (3)**

AI/ML FOR ENGINEERING ANALYSIS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of statistics for Machine learning/deep learning
CO-2	Explore various supervised and unsupervised techniques for Machine learning and Deep learning
CO-3	Learn the programming skills for applying to ML/DL algorithms
CO-4	Apply the above skills to solve design and analysis problems
CO-5	Synthesize cams and followers for specified motion profiles

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Basics of Engineering Design and Statistics: Introduction to Statistics – descriptive statistics, dispersion measures, central tendency measures, hypothesis testing, inferential statistics, correlation and regression, p-value, central limit theorem, feature engineering

Machine Learning Algorithms: Basics of AI, ML, & DL. Fundamentals of ML - supervised, unsupervised, reinforcement learning. Supervised machine learning – Regression: linear regression, multilinear regression, non-linear regression, logistic regression. Classification: neural networks, decision trees, random forests, support vector machine, k-nearest neighbor. Unsupervised machine learning – mixture models, hierarchical k-means clustering, principal component analysis

Deep learning Algorithms: Deep feedforward neural nets, Convolutional neural networks, Long short-term memory (LSTM) networks. Introduction to Graph Neural networks, Generative Adversarial Networks, and Reinforcement Learning

Python for Machine Learning: Getting started with Python, Basic Commands, working with Python libraries, Loops, Variables, Data types, and Data visualization, exploring AI through python- neural networks and machine learning in python.

Applications: SHM Paradigm, feature extraction, feature importance, correlation, and eigenvalue analyses, feature augmentation, performance and validation of ML/DL models in mechanical engineering applications

Learning Resources:

Text Books:

1. Thomas Nield, Essential math for data science, Oreilly, June 2022

Reference Books:

1. Marc peter, Aldo Faisal, Cheng soon, Mathematics for Machine learning, Cambridge, 2021

ME46024 **3-0-0 (3)**

CONDITION MONITORING AND FAULT DIAGNOSTICS

Prerequisites: **None**

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 maintenancetechniques, 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

ME46028 **3-0-0 (3)**

OPTIMIZATION METHODS FOR ENGINEERING DESIGN

Prerequisites: None

Course Outcomes:

CO-1	Formulate a design task as an optimization problem.
CO-2	Solve unconstrained optimization problems using corresponding methods.
CO-3	Solve unconstrained optimization problems using corresponding methods.
CO-4	Solve the nonlinear optimization problems with evolutionary methods

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

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 Unconstrained 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 and gradient based methods for constrained optimization. Formulation and Case studies.

Evolutionary Optimization algorithms: Philosophy**,** Genetic algorithms and simulated annealing.

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:

Text Books:

1. Jasbir Arora, Introduction to Optimum Design, Academic Press, 2004.

Reference Books:

1. Kalyanmoy Deb, Optimization For Engineering Design: Algorithms and Examples, PHI, 2004.
2. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley, 2001

ME46032 **3-0-0 (3)**

ROTOR DYNAMICS

Prerequisites: None

Course Outcomes:

CO-1	Model the Rotor bearing systems and formulate the governing equations.
CO-2	Understand the role of damping, gyroscopic, centrifugal, stiffness and inertialeffects on rotors.
CO-3	Compute the critical speeds and stability limits for rotors under axial, transverseand torsional modes.
CO-4	Analyse the rotor bearing systems using transfer matrix method and FiniteElement Method.
CO-5	Compute the transient response of rotors.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Introduction to rotor dynamics, Rotating and reciprocating unbalances, Classification of Discrete and continuous systems, Review of free and forced vibrations of single and multi-degree of freedom systems.

Linear Rotor Dynamics : Equation of motion, Rotating systems, Complex coordinate representation, Undamped Jeffcott Rotor – Free whirling, Unbalance response, Shaft Bow Jeffcott Rotor with viscous damping – Free whirling, Unbalance response, Shaft Bow With structural damping – Free whirling, Unbalance response, frequency dependent loss factors with non-synchronous damping, Effect of Bearing Compliance,Stability in supercritical region.

Modelling with Four Degrees of Freedom: Generalised coordinates and equations of motion in real and complex coordinates, Static and couple unbalance and their effects, uncoupled gyroscopic systems, Free whirling of coupled undamped systems, Unbalance response and Shaft bow. Model uncoupling of gyroscopic systems, Configuration and state space approaches.

Discrete multi-degree of freedom: Introduction, Transfer matrix approach for undamped systems, Damped systems, The finite element method for rotors, Beam elements, spring elements, Mass elements, Assembly and constraints, Damping matrices, Choice of coordinates: fixed Vs Rotating and Real Vs Complex coordinates, Computation of critical speeds, Computation of unbalance response. Campbell and root locus diagrams, Reduction of DOF: Nodal reduction, model reduction and component mode synthesis.

Transmission Shafts: Modelling of rotors as continuous systems, Euler-Bernoulli and Timoshenko beam models, Dynamic stiffness, Analytical and approximate solutions.

Anisotropy of rotors and supports: Isotropic rotors on Anisotropic supports – Influence of damping, non-isotropic rotors on isotropic supports.

Rotor-Bearing Interaction: Rigid body and flexural modes, Linearization of bearing Characteristics, Rolling element bearings, Fluid film bearings, Magnetic bearings, bearing alignment in multi rotor bearings

Learning Resources:

Text Books:

1. Giancarlo Genta, Dynamics of Rotating Systems, Springer, 2009
2. Rao, J.S., Rotor Dynamics, New Age International, 2003, 3 Edition.

Reference Books:

1. Chong-Won Lee, Vibration Analysis of Rotors, Kluwer Academic Publishers, London, 1995
2. Muszynska A, Rotor dynamics, Taylor & Francis, New York, 2005

Other Suggested Readings:

ME46034 **3-0-0 (3)**

TRIBOLOGY IN DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze properties of lubricant and select proper lubricant for a given application.
CO-2	Identify tribological performance parameters of sliding contact in different lubrication regimes.
CO-3	Design and select appropriate bearings for a given application
CO-4	Predict the type of wear and volume of wear in metallic and polymer surfaces

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

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

Lubricants: Types of lubricants, Objectives of lubricant, Physical properties of lubricants, Selection of lubricant.

Lubrication modes and Theories of lubrication: Modes of lubrication - hydrodynamic, hydrostatic, Elasto-hydrodynamic, mixed and boundary lubrication, 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.

Friction and Wear: Origin of sliding friction, Contact between two bodies in relative motion, Types of wear and their mechanisms - Adhesive wear, Abrasive wear, Wear due to surface fatigue and wear due to chemical reactions, wear of metallic materials, Tribology of polymers.

Special topics: Bio-tribology, Introduction to MEMS, Nano Tribology and Space Tribology

Learning Resources:

Text Books:

1. Stachowaik, G.W., Batchelor, A.W., Engineering Tribology, Elsevier, 2010, 3rd Edition.
2. Majumdar B.C, Introduction to bearings, S. Chand & Co., Wheeler publishing, 1999.
3. Andras Z. Szeri, Fluid film lubrication theory and design, Cambridge University press, 1998..

Reference Books:

1. TA Stolarski, Tribology in Machine Design, Butterworth-Heinemann, 2000.
2. Williams JA, Engineering Tribology, Oxford Univ. Press, 2001.
3. Cameron A, Basic lubrication theory, Ellis Horwood Ltd., 2002.
4. Neale MJ, Tribology Hand Book, CBS Publications, 2012.
5. Harish Hirani, Fundamentals of Engineering Tribology with Applications, Cambridge University press, 2016

ME46036 **3-0-0 (3)**

CHARACTERIZATION OF ENGINEERING MATERIALS

Prerequisites: None

Course Outcomes:

CO-1	Identify advanced techniques available for characterization of materials
CO-2	Select a characterization technique to evaluate the behavior of materials
CO-3	Analyze defects and failure surfaces of materials
CO-4	Analyze the characterization results by various equipment

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

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:

Text Books:

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2010, 4th edition.
2. Yang Leng, Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd, 2008.
3. Dieter,George E, Mechanical Metallurgy, McGraw Hill, 2nd Edition, 2005

Reference Books:

1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. V. T. Cherapin and A. K. Mallik, Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.
3. Crawford, R. J., Plastics Engineering, Butterworth-Heinemann, 3/e, 2002.
4. Donachie, M. J. and Donachie, S. J., Super alloys: A technical guide, ASM International, 2002

ME46040 **3-0-0 (3)**

NOISE, VIBRATIONS AND HARSHNESS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic terminologies of Noise, Vibration, Harshness and Safety.
CO-2	Acquire Comprehensive, knowledge of Sources of Vibration and Noise applicable to the automobile engineering discipline and possibility of modifications and improvements.
CO-3	Apply engineering techniques, tools, for measurement methods in order to learn to control and solve complex Vehicle performance problems.
CO-4	Analyze the principles of safety of automobile under different road and environment and load condition.
CO-5	Design processes for eliminating or reducing the Vibration, Noise to reduce irritation to occupants and achieve improvement in perception of ride comfort.

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

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.

Characteristics & Sources of Vibrations: Free and Forced Vibration, Natural Frequency, Un-Damped & Damped Vibrations, Unit Impulse, Vibration Isolation, Transmissibility. Power Train: Engine, Clutch, Transmission, Propeller shaft, 3 Differential, Drive shaft, Trans axle. Power train mounts.

Sources of Noise, Measurement Technics and Control: Noise specifications and mandatory standards regulations. Brake Squeal noise, Pass-by Noise, wind noise, squeak noise and rattle, interior noise (including noise emitted by running of accessories, indicators and all buzzers). Power train, Engine Air Intake & Exhaust noise, Engine accessories, cooling system and vehicle body protrusion noise, under body protrusion noise. Noise due to Tyre-Road friction and slip characteristics.

Noise Measuring Instruments: Microphone, Sound intensity probes. Noise Control: Damping treatment methods, Control through isolations and noise absorbing materials and structure. Active and semi-active control of noise. Study of anechoic chamber.

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

Harshness: Definition. Its effect and acceptable degree of Harshness. Perception of Ride comfort i.e. psychological effects of Noise & Vibrations. Study of NVH - Legislations applicable for vehicles in India.

Safety: Passive safety Active safety, Study of Safety Regulations for vehicular application.

Learning Resources:

Text Books:

1. Chen, G.S., Vehicle Noise Vibration and Sound Quality. SAE International, 2012,
2. D. G. Karczub, M.P Norton, Fundamentals of Noise and Vibration Analysis for Engineers by Cambridge University Press,2003, 2nd Edition
3. S.S.Rao , Mechanical Vibrations, Pearson, 2018, 6th Edition
4. W.T.Thomson & M.D.Dahleh, Theory of Vibration with Applications, by, Pearson Education,2008, 5th Edition.
5. J.K.Thompson, Brake NVH Testing and Measurements by, SAE International Publications,2011

Reference Books:

1. Baxa, Donald E.; Petska, Darrell E., Noise Control of Internal Combustion Engine, New York John Wiley and Sons, 1982, 1st Edition.
2. Munjal N.S, Acoustic Duct and Mufflers John Wiley Publications, 2nd Edition.
3. Vibrations and Noise for Engineers, Kewal Pujara, Dhanpat Rai & Co.,2018,
4. Rao V. Dukkipati and J. Srinivas; Text Book of Mechanical Vibrations, PHI, 2012, 2nd Edition

ME46034 **2-0-2 (3)**

Design Thinking for Engineering Applications

Pre-Requisites: None — Basic engineering background is sufficient. ME 46033 is recommended but not mandatory.

Course Outcomes:

CO1	Understand the principles, mindsets, and methodology of Design Thinking and human-centred design in the context of engineering products, processes, and systems.
CO2	Apply user research methods — observation, contextual inquiry, and interviewing — to empathise with engineering stakeholders and synthesise insights into precise Point of View (POV) problem statements.
CO3	Generate and develop creative solution concepts for engineering design challenges using structured ideation methods, concept development tools, and cross-domain analogical thinking.
CO4	Construct low-fidelity prototypes and design structured tests to validate engineering design concepts, interpret user feedback, and make evidence-based iteration decisions.
CO5	Design a complete human-centred solution for a complex engineering problem by integrating Design Thinking methodology with awareness of system-level consequences and sustainability considerations.

CO-PO Correlation Matrix

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

Legend: 1 – Slightly; 2 – Moderately; 3 – Substantially

Detailed Syllabus

Foundations of Design Thinking: Introduction to DT — human-centred design; DT vs traditional engineering design process; Stanford d.school framework: Empathise, Define, Ideate, Prototype, Test — iterative cycle; Divergent and convergent thinking; the Double Diamond model; DT and Systems Thinking together; Case studies — Toyota Production System as DT; Tata Nano; vehicle instrument cluster reframing.

Empathise and Define: User research methods — observation, contextual inquiry, shadowing, semi-structured interviews; Synthesising research — affinity mapping, insight statements, moving from data to meaning; Point of View (POV) statement: [User] needs [need] because [insight]; How Might We (HMW) questions; problem framing and reframing; the Define stage as leverage point.

Ideate: Creative ideation principles — brainstorming, deferred judgement, psychological safety; Structured methods — brainwriting, SCAMPER, analogical thinking; TRIZ inventive principles; Concept development — morphological charts, concept sketching, concept combinations; Concept selection — Pugh matrix, weighted decision matrix; connecting ideation to ST leverage points.

Prototype and Test: Prototyping principles — fidelity spectrum; physical, process, and interface prototypes; Low-fidelity methods — paper prototyping, cardboard models, storyboards, process walk-throughs; Testing protocols — test design, observation, capturing feedback; iteration and the pivot decision; Engineering prototyping in the DT process; failure as learning; documenting iteration rationale.

Design Thinking in Engineering Practice: DT in engineering product development — integrating DT into the V-model and stage-gate process; DT in process and system design — redesigning manufacturing processes and engineering interfaces; DT and sustainability — human-centred sustainability; rebound effect; circular economy design; Scaling design solutions — from prototype to pilot to implementation; capstone project reviews.

Experiential Practice and Capstone Project Work:

Student teams complete a full Design Thinking cycle on a real Mechanical Engineering problem: user research and empathy mapping, Point of View (POV) statement, How Might We (HMW) questions, structured ideation, low-fidelity prototype, user test, and iteration. Final deliverable: user research report, prototype documentation, test results, and a systems-aware intervention recommendation presented to the class in Week 14.

Learning Resources:

Text Books:

1. Nigel Cross, Engineering Design Methods: Strategies for Product Design, 5th Edition, John Wiley & Sons, 2021.
2. Tim Brown, Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation, HarperBusiness, 2009.
3. Nigel Cross, Design Thinking: Understanding How Designers Think and Work, Berg Publishers, 2011.

Reference Books:

1. Don Norman, The Design of Everyday Things, Revised and Expanded Edition, Basic Books, 2013.
2. IDEO.org, The Field Guide to Human-Centered Design, IDEO.org, 2015. (Free PDF at designkit.org)
3. Jeanne Liedtka & Tim Ogilvie, Designing for Growth: A Design Thinking Tool Kit, Columbia University Press, 2011.
4. Vijay Kumar, 101 Design Methods: A Structured Approach for Driving Innovation, John Wiley & Sons, 2013.
5. Darrell Mann, Hands-On Systematic Innovation, 2nd Edition, Creax Press, 2007.