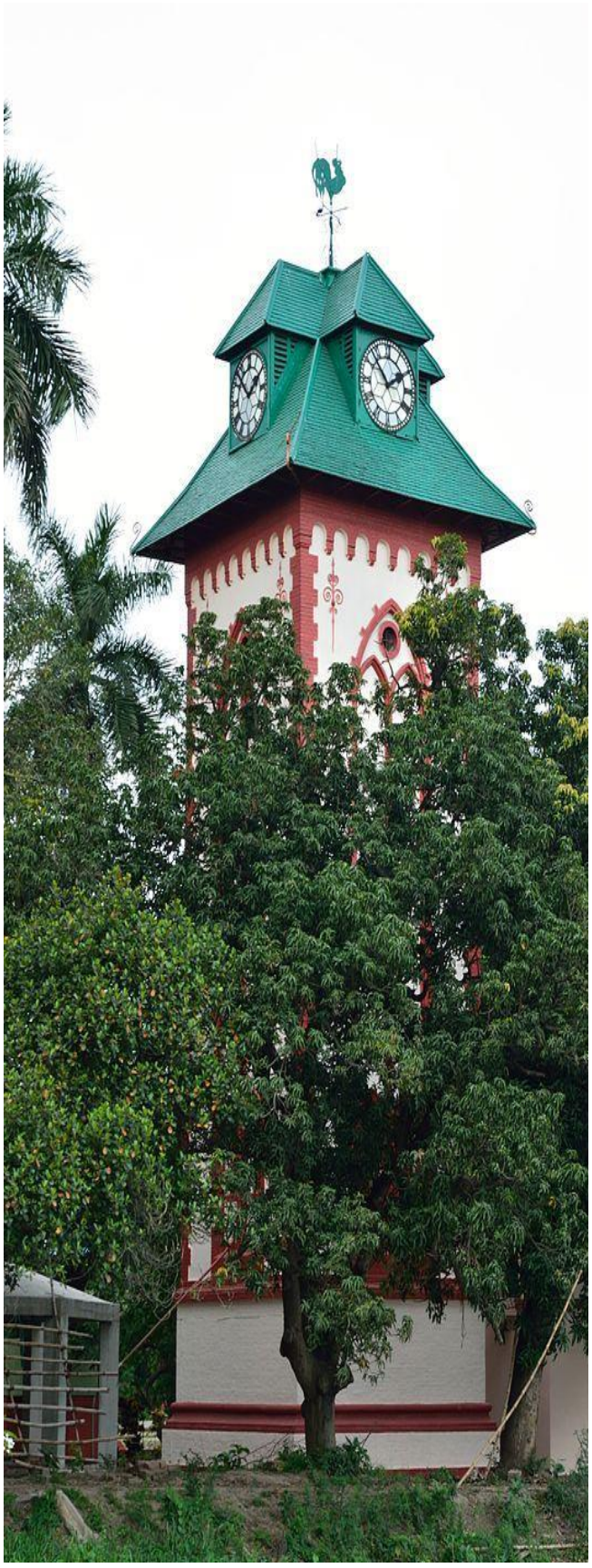

Mechanical Engineering

M. Tech. Program

Course Structure and Syllabus

(Effective from 2025-26 admitting batch onwards)

Indian Institute of Engineering Science and Technology (IIEST), Shibpur

Botanic Garden, Howrah

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Course Structure

Thermal Science and Energy Technology

A. First Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	PC	Advanced Engineering Thermodynamics	ME-5101N	3	0	0	3	100
2	PC	Solar, Wind & Biomass Energy Systems	ME-5102N	3	0	0	3	100
3	PC	Advanced Fluid Mechanics	ME-5103N	3	0	0	3	100
4	PSE	List below		3	0	0	3	100
5	OE	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal				**15**	**0**	**0**	**15**	**500**
6	PC	Thermal Simulation Laboratory	ME-5171N	0	0	3	2	50
7	PC	Renewable Energy Laboratory	ME-5172N	0	0	3	2	50
8	PC	CFD Laboratory	ME-5173N	0	0	3	2	50
Practical Subtotal				**0**	**0**	**9**	**6**	**150**
First Semester Total				**15**	**0**	**9**	**21**	**650**

List of Departmental and Open Electives for First Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5121N	Combustion Science and Technology
Departmental Elective	ME-5122N	Design of Refrigeration & Air-conditioning Systems
Departmental Elective	ME-5123N	Gas Turbines and Jet Propulsion
Departmental Elective	ME-5124N	Greenhouse Technology
Departmental Elective	ME-5125N	Energy, Environment & Economics
Departmental Elective	ME-5126N	Nuclear Power Engineering
Departmental Elective	ME-5141N	Machine Learning for Mechanical Engineers
Open Elective	ME-5161N	Renewable and Alternative Energy

B. Second Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	PC	Hydrogen Energy & Fuel Cells	ME-5201N	3	0	0	3	100
2	PC	Advanced Energy Storage Systems	ME-5202N	3	0	0	3	100
3	PC	Advanced Heat Transfer	ME-5203N	3	0	0	3	100
4	PSE	List below		3	0	0	3	100
5	OE	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
		Theory Subtotal		**15**	**0**	**0**	**15**	**500**
6	P	M. Tech. Project Part - I (Term Paper)	ME-5291N	0	0	3	4	50
7	O	Term Paper Seminar & Viva-voce	ME-5292N	0	0	3	2	50
		Practical Subtotal		**0**	**0**	**6**	**6**	**100**
		Second Semester Total		**15**	**0**	**6**	**21**	**600**

List of Departmental and Open Electives for Second Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5221N	Numerical Heat Transfer & Fluid Flow
Departmental Elective	ME-5222N	Energy Efficient Buildings
Departmental Elective	ME-5223N	Cryogenic Systems and Equipment
Departmental Elective	ME-5224N	Clean Coal Technology
Departmental Elective	ME-5225N	Carbon Capture & Storage
Departmental Elective	ME-5226N	IC Engines & Electric Vehicles
Open Elective	NO OPEN ELECTIVES ARE OFFERED	

C. Third Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	VAC	Carbon Footprint & Carbon Audit		3	0	0	3	100
2	P	M. Tech. Project Part - II (Progress Report)	ME-6191N	0	0	24	12	300
3	O	Progress Report Seminar & Viva-voce	ME-6192N	0	0	0	6	100
4	I	Summer internship (6-8 weeks) evaluation		0	0	0	2	50
Third Semester Total				**3**	**0**	**24**	**23**	**550**

D. Fourth Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	P	M. Tech. Final Thesis	ME-6291N	0	0	30	22	400
2	O	Thesis Seminar & Viva-voce	ME-6292N	0	0	0	8	200
Fourth Semester Total				**0**	**0**	**30**	**30**	**600**

Course Structure
Machine Design

A. First Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	PC	Advanced Solid Mechanics	ME-5106N	3	0	0	3	100
2	PC	Linear and Non-Linear Vibration	ME-5107N	3	0	0	3	100
3	PC	Geometric Modelling for CAD	ME-5108N	3	0	0	3	100
4	PSE	List below		3	0	0	3	100
5	OE	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal				**15**	**0**	**0**	**15**	**500**
6	PC	Mini Project on Advanced Solid Mechanics	ME-5176N	0	0	3	2	50
7	PC	Vibration Laboratory	ME-5177N	0	0	3	2	50
8	PC	Geometric Modelling for CAD Laboratory	ME-5178N	0	0	3	2	50
Practical Subtotal				**0**	**0**	**9**	**6**	**150**
First Semester Total				**15**	**0**	**9**	**21**	**650**

List of Departmental and Open Electives for First Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5141N	Machine Learning for Mechanical Engineers
Departmental Elective	ME-5132N	Engineering Tribology
Departmental Elective	ME-5133N	Applied Elasticity and Plasticity
Departmental Elective	ME-5134N	Advanced Mechanics of Machines
Departmental Elective	ME-5135N	Design Optimization
Departmental Elective	ME-5136N	Biomechanics
Open Elective	ME-5162N	Industrial Robotics

B. Second Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	PC	Fatigue, Creep and Fracture Mechanics	ME-5206N	3	0	0	3	100
2	PC	Control of Mechanical Systems	ME-5207N	3	0	0	3	100
3	PC	Computational Mechanics of Solids	ME-5208N	3	0	0	3	100
4	PSE	List below		3	0	0	3	100
5	OE	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal				**15**	**0**	**0**	**15**	**500**
6	P	M. Tech. Project Part - I (Term Paper)	ME-5291N	0	0	3	4	50
7	O	Term Paper Seminar & Viva-voce	ME-5292N	0	0	3	2	50
Practical Subtotal				**0**	**0**	**6**	**6**	**100**
Second Semester Total				**15**	**0**	**6**	**21**	**600**

List of Departmental/Open Electives for Second Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5231N	Introduction to Modern Materials
Departmental Elective	ME-5232N	Bearing Lubrication
Departmental Elective	ME-5233N	Design of Piping Systems
Departmental Elective	ME-5234N	Non-Destructive Testing of Materials
Departmental Elective	ME-5235N	Industrial Tribology
Departmental Elective	ME-5236N	Data-Driven Dynamical Systems
Open Elective	NO OPEN ELECTIVES ARE OFFERED	

C. Third Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	VAC	Carbon Footprint & Carbon Audit		3	0	0	3	100
2	P	M. Tech. Project Part - II (Progress Report)	ME-6191N	0	0	12	12	300
3	O	Progress Report Seminar & Viva-voce	ME-6192N	0	0	0	6	100
4	I	Summer internship (6-8 weeks) evaluation		0	0	0	2	50
Third Semester Total				**3**	**0**	**12**	**23**	**550**

D. Fourth Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	P	M. Tech. Final Thesis	ME-6291N	0	0	30	22	400
2	O	Thesis Seminar & Viva-voce	ME-6292N	0	0	0	8	200
Fourth Semester Total				**0**	**0**	**30**	**30**	**600**

Course Structure

Advanced Manufacturing Technology

A. First Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	PC	Industrial Engineering	ME-5111N	3	0	0	3	100
2	PC	Non-Traditional Machining	ME-5112N	3	0	0	3	100
3	PC	Advanced Material Processing Technology	ME-5113N	3	0	0	3	100
4	PSE	List below		3	0	0	3	100
5	OE	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal				**15**	**0**	**0**	**15**	**500**
6	PC	Industrial Engineering Laboratory / Mini project	ME-5181N	0	0	3	2	50
7	PC	Non-Traditional Machining Laboratory	ME-5182N	0	0	3	2	50
8	PC	Advanced Material Processing Technology Laboratory	ME-5183N	0	0	3	2	50
Practical Subtotal				**0**	**0**	**6**	**6**	**150**
First Semester Total				**15**	**0**	**6**	**21**	**650**

List of Departmental/Open Electives for First Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5141N	Machine Learning for Mechanical Engineers
Departmental Elective	ME-5142N	Design of Production Systems
Departmental Elective	ME-5143N	Industrial Automation
Departmental Elective	ME-5144N	Quality Engineering
Departmental Elective	ME-5145N	Mechanical Testing & Characterization
Open Elective	NO OPEN ELECTIVES ARE OFFERED	

B. Second Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	PC	Computerized Manufacturing	ME-5211N	3	0	0	3	100
2	PC	Additive Manufacturing Technology	ME-5212N	3	0	0	3	100
3	PC	Micro & Nano Manufacturing	ME-5213N	3	0	0	3	100
4	PC	List below		3	0	0	3	100
5	OE	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal				**15**	**0**	**0**	**15**	**500**
6	P	M. Tech. Project Part - I (Term Paper)	ME-5291N	0	0	3	4	50
7	O	Term Paper Seminar & Viva-voce	ME-5292N	0	0	3	2	50
Practical Subtotal				**0**	**0**	**6**	**6**	**100**
Second Semester Total				**15**	**0**	**6**	**21**	**600**

List of Departmental/Open Electives for Second Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME 5241N	Quantitative Techniques in Production Management
Departmental Elective	ME 5242N	Operations Management
Departmental Elective	ME 5243N	Advanced Material Management
Departmental Elective	ME 5244N	Material Handling
Departmental Elective	ME 5245N	Maintenance and Reliability
Departmental Elective	ME 5246N	Advanced Machining Technology
Departmental Elective	ME 5247N	Energy Beam Processing of Materials
Departmental Elective	ME 5248N	Advanced Operations Research
Departmental Elective	ME 5249N	Metal Forming
Open Elective	NO OPEN ELECTIVES ARE OFFERED	

C. Third Semester

Sl. No.	Paper	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	VAC	Carbon Footprint & Carbon Audit		3	0	0	3	100
2	P	M. Tech. Project Part - II (Progress Report)	ME-6191N	0	0	24	12	300
3	O	Progress Report Seminar & Viva-voce	ME-6192N	0	0	0	6	100
4	I	Summer internship (6-8 weeks) evaluation		0	0	0	2	50
Third Semester Total				**3**	**0**	**24**	**23**	**550**

D. Fourth Semester

Sl. No.	Type	Course Name	Course Code	Load/Week			Credit	Marks
				L	T	P		
1	P	M. Tech. Final Thesis	ME-6291N	0	0	30	22	400
2	O	Thesis Seminar & Viva-voce	ME-6292N	0	0	0	8	200
Fourth Semester Total				**0**	**0**	**30**	**30**	**600**

Course Curriculum
for
Thermal Science and Energy Technology

Course Code	ME5101N	Course Name	Advanced Engineering Thermodynamics	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Thermodynamics	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	Mechanical Engineering			Data Book / Codes/Standards	*Nil*

Course Objective	• To review the laws of basic thermodynamics, entropy changes and irreversibility. • To introduce the concept of availability and exergy analysis in thermal systems. • To study thermodynamic properties and behaviour of real gases and mixtures using different equations of state • To apply advanced thermodynamic relations to determine property variations • To analyze reacting systems considering equilibrium, heat of reaction, flame temperature, and second law analysis.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Review of Thermodynamics Laws: First law efficiency, Reversibility, Clausius inequality, Principle of increase of entropy, Entropy change due to mixing of fluids, Entropy generation	07	Student should be able to recapitulate different laws of thermodynamics reversibility and entropy,.
2.	Availability and Exergy: Quality of energy, Dead state, Exergy of closed system and open system, Exergy in chemical reactions, Helmholtz function, Gouy-Stodola theorem and it applications, Second law efficiency, Exergy analysis of simple power cycle and refrigeration cycle	07	Should understand the concept of availability and exergy and apply to various power and cooling cycles
3.	Properties of Gases and Gas Mixtures: Different equations of state for real gases, Compressibility factor, Law of corresponding states, Dalton's law of partial pressure, Internal energy, Enthalpy, Specific heats and Gibbs Function of gas mixture	07	Student should be able to apply the basic thermodynamics laws to real gases and mixture of gases
4	ThermodynamicsRelations:Maxwell'sequations,DifferentTdSequations, Relation between different heat capacities, Energy equation, Joule-Kelvin effect, Inversion curve, Clausius Clapeyron equation, Mixture of variable composition, Gibbs phase rule	07	Should know how to apply advanced thermodynamic relations to analyze energy interactions, phase behaviour and mixtures of variable composition.
5.	Reactive Systems: Degree of reaction, Reaction equilibrium, Law of mass action, Heat of reaction and enthalpy of combustion, Nernst's equation,Thermal ionization of mono-atomic gas, Saha's equation, Adiabatic flame temperature, Fugacity and activity, Second law analysis of reactive system	07	Should be able to understand and apply thermodynamic principles to reactive systems, including chemical equilibrium, heat of reaction, adiabatic flame temperature and ionization.

6.	Analysis of different engineering cycles: combined cycle and cogeneration	04	Should be able to understand combined and cogeneration cycles for improved efficiency.
Total		**39**	

Course Outcome	**CO1.** Analyze thermodynamic processes for efficiency and entropy generation. **CO2.** Understand and evaluate exergy and second law efficiency in thermal systems **CO3.** Determine properties of real gases and mixtures using appropriate EOSs **CO4.** Apply thermodynamic relations to compute property and phase changes. **CO5.** Understand the reactive systems thermodynamics including different laws and equations. **CO6.** Evaluate performance of combined and cogeneration cycles.

Learning Resources	**Text Books:** 1. Nag,P.K. Engineering Thermodynamics, FifthEdition,2013,McGraw-Hill Education(India)Private Limited 2. Boles,M.A and Yungus A.Cengel, Y.A. Thermodynamics: An Engineering Approach, Eighth Edition, 2015, McGraw-Hill Education (India) Private Limited **Reference Books:** 1. Rogers, G.F.C and Mayhew, Y. Engineering Thermodynamics: Work and Heat Transfer, Fourth Edition, 2002, Pearson 2. Heywood, R.W. Analysis of Engineering Cycles, FourthEdition,1992,Pergamon

Course Code	ME5102N	Course Name	Solar, Wind and Biomass Energy Systems	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department		*Mechanical Engineering*		**Data Book / Codes/Standards**	*NIL*

Course Objective	**CO1:** To introduce the fundamental principles of solar radiation and solar geometry and their application in estimating and measuring solar energy for engineering use. **CO2:** To develop a deep understanding of solar thermal and photovoltaic systems, including components, design principles and real-world applications such as water heating, desalination, refrigeration and solar power plants. **CO3:** To familiarize students with wind energy conversion systems, their aerodynamics, site selection, design and electricity generation performance. **CO4:** To explore the various types and conversion methods of biomass, including waste-to-energy technologies. **CO5:** To prepare students for applying scientific and engineering principles in analyzing, designing and optimizing renewable energy systems.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Solar radiation, Classification of solar radiation: Beam solar radiation, Diffuse solar radiation, Global solar radiation. Solar radiation geometry: Latitude of location, Declination, Hour angle, Slope of surface, Altitude angle, Zenith angle, Solar azimuth angle, Local solar time, Equation of time. Estimation of solar radiation: Average daily global radiation, Average daily diffuse radiation, Hourly global radiation, Hourly diffuse radiation, Angle of incidence on horizontal surface, Angle of incidence on inclined surface, Computation of solar radiation on tilted surface. Measurements of solar radiation: Pyranometer, Pyrheliometer, Sunshine recorder, Spectral measurements, Calibration and standardization of measuring instruments.	07	Understand the principles of solar radiation, its classification, geometric parameters, methods of estimation and techniques for measurement using standard instruments.
2.	Solar Power Generation applications: Basic overview of solar collectors, Concentrating Solar collector, Flat Plate Collector and its performance analysis, Solar water heating, Solar cooking, Solar desalination, Solar drying of food products, Solar energy for industrial process heat, Solar active heating of buildings, Solar passive heating of buildings, Solar greenhouses, Solar refrigeration, Solar Power Tower Plant, Solar Pond	07	Gain knowledge of various solar power generation technologies and their applications in domestic, industrial and agricultural sectors.
3.	Fundamentals of photovoltaic conversion, Efficiency of solar cells, Solar modules and array, Balance of system (BOS), Standalone system, Grid independent system, Grid	07	Understand the fundamentals of photovoltaic energy

	interactive system, Photovoltaic applications		conversion, system components, configurations and practical applications in standalone and grid-connected setups.
4	Introduction of wind energy, General theories of wind machines, Basic laws and concepts of aerodynamics, Micro-siting, Description and performance of the horizontal–axis wind machines, Blade design, Description and performance of the vertical–axis wind machines, The generation of electricity by wind machines, case studies	07	Understand the principles of wind energy conversion, aerodynamics, wind turbine design, site selection and performance analysis through practical case studies.
5.	Biomass resources, types, production, classification and characterization; Techniques for biomass assessment. Concept of Waste segregation, management and treatment. Thermochemical Conversion: Direct combustion, incineration, pyrolysis. Biomass gasifiers; types of gasifiers, Sizing selection and design of gasifiers. Biomass stoves, improved chulha and designs. Biomass fired boilers and types; Biomass pyrolysis – types, manufacture of charcoal, manufacture of pyrolytic oils and gases; Design and operation of pyrolysis units. Plastic waste management, plastic pyrolysis type of technologies. Co-firing and co-generation. Physiochemical Conversion: Biodegradation substrate; Anaerobic digestion, biomethanation process, biogas plant types, biogas plant design, biogas purification and utilisation; bioconversion of substrates into bioethanol; Concept of Biorefinery, Biodiesel and biohydrogen production; Solvent extraction of hydrocarbons	07	Understand biomass resources, waste management techniques and various thermochemical and physiochemical conversion processes for sustainable energy production.
6.	Introduction to Energy from waste, classification of waste as fuel, agro based, forest residue, industrial waste, Environmental monitoring system for land fill gases, Environmental impacts; Measures of mitigate environmental effects due to incineration.	04	Understand the potential of waste as an energy source, its classification, environmental impacts and mitigation measures including landfill gas monitoring and incineration control.
Total		**39**	

Course Outcome	After this course, students will be able to understand the principles and applications of various renewable energy technologies including solar, wind, biomass and waste-to-energy systems. They will gain knowledge of energy conversion mechanisms, system components, environmental impacts and performance evaluation methods. This will enable them to analyze and design sustainable energy solutions for real-world applications.

Learning Resources	**Text Books:** 1. S. P. Sukhatme, Solar Energy - Principles of thermal collection and storage, second edition, Tata McGraw-Hil, New Delhi, 1996. 2. Solar Energy Fundamentals and Applications by H. P. Garg and J. Prakash, Tata Mc GrawHill Publishing Company Limited. 3. Solar Energy Fundamentals, Design, Modelling and Applications by G. N. Tiwari, Narosa Publishing House. 4. Wind energy Conversion Systems – Freris L.L. (Prentice Hall1990). 5. Capareda S, Introduction to biomass energy conversion, CRC Press. ISBN: 978-1-466-51333-4 6. Brown RC and Stevens C, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Wiley and Sons. ISBN: 978-0-470-72111-7 Reference Books: 1. F.D. Bianchi, H.D. Battista and R.J. Mantz, Wind Turbine Control Systems- Principles, Modelling and Gain Scheduling Design, Springer, 2007. 2. Mehmet Kanoglu, Yunus A. Cengel, John M. Cimbala, Fundamentals and Applications of Renewable Energy, 2020, McGraw Hill. 3. B.H. Khan, Non-conventional Energy Resources, 2017, Third Edition, McGraw Hill. 4. Mehmet Kanoglu, Yunus A. Cengel, John M. Cimbala, Fundamentals and Applications of Renewable Energy, 2020, McGraw Hill. 5. B.H. Khan, Non-conventional Energy Resources, 2017, Third Edition, McGraw Hill. 6. Vaughn C. Nelson, Kenneth L. Starcher, Introduction to Bioenergy (Energy and the Environment), CRC Press. ISBN: 978-1-498-71698-7 7. Yebo Li and Samir Kumar Khanal, Bioenergy: Principles and Applications, Wiley-Blackwell. ISBN: 978-1-118-56831-6 8. Ted Weyland, Bioenergy: Sustainable Perspectives, Callisto Reference. ISBN: 978-1-632-39633-4

Course Code	ME5103N	Course Name	Advanced Fluid Mechanics	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	Numerical Methods in Heat Transfer
Course Offering Department	Mechanical Engineering			Data Book / Codes/Standards	*Nil*

Course Objective	The course will enable students to: • Understand each term of the conservation laws and apply them for fluid flow • Analyse viscous flow phenomena • Understand and evaluate compressible flow problems • Develop analytical skills to solve complex flow problems

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	**Introduction:** Properties of fluid , Continuum hypothesis, Real life viscous flow phenomena, Laminar and Turbulent Flow, Tensor notations, Lagrangian and Eulerian Methods, Streamline, Pathline, Streakline, Material Derivative and acceleration, Strain Rate, Translation, Rotation and Distortion of Fluid Element, Vorticity and Circulation.	04	Students will understand different fluid and flow properties
2.	**Conservation Equations:** Conservation of Mass, Momentum and Energy, Derivation of Continuity Equation: conservative and non-conservative form, Derivation of Navier-Stokes equations, Stokes Hypothesis. N-S equations forms for incompressible flow	04	Students will understand each term of the conservation equations
3.	**Exact solutions of Navier-Stokes Equations:** Fully developed Parallel Flow in a Straight Channel, Flow between concentric rotating cylinders, Couette Flow, Flow of two immiscible fluids in a channel, Parallel flow of power law fluids, Lubrication Theory, Hagen-Poiseuille Flow, Unsteady Parallel Flow, Stokes Problems, Similarity Solution and Creeping Flow, Complex variable and Potential flow.	07	Students will be able to formulate and solve real flow problems.
4	**Boundary Layer Theory:** Derivation of 2-D Boundary Layer Equations, Displacement, Momentum and Energy Thickness, Order of Magnitude Analysis, Shape Factor, Momentum-Integral Approach, Boundary Layer Separation, Effect of Pressure Gradient, Boundary Layer Control mechanism, Blassius Solution of Boundary Layer Equation, Kármán-Pohlhausen Method for flow over a flat plate, Kármán-Pohlhausen Method for Non-Zero Pressure Gradient, Waltz's-Approximations.	06	Students will be made aware of boundary layer theory and integral method.
5.	**Flow Instability:** Instability, Concept of Small-Perturbations, Linearized Stability of Parallel Viscous	04	Students will be introduced to stability

	Flows, Orr-Sommerfeld Equation, Neutral Stability Curve, Boundary Layer Transition over a Flat Plate,		analysis.
6.	**Turbulent Boundary Layers:** Introduction to Turbulent Flows, Characteristics of Turbulence, Laminar Turbulent transitions, Energy Cascade, Mean and Fluctuating Components, Derivations of Reynolds Averaged Navier-Stokes Equations, Reynolds Stress Tensor, Turbulent Boundary Layer Equations, Eddy Viscosity and Mixing Length Hypothesis, Universal Law of Wall, Laminar Sub layer, Power Law for Turbulent Boundary Layer, Skin Friction Coefficient, Turbulent Boundary Layer with Pressure Gradient, The dynamic of Turbulence.	05	Students will be able to formulate, analyse and evaluate turbulent flow problems.
7	**Internal Flows:** Fully Developed Turbulent Flow through a Pipe and Channel, Use of Log Law and Power Law, Derivation of Coefficient of Friction for Turbulent Pipe Flow, Moody Diagram, Hydrodynamic Smooth and Rough Pipe and Example Problems	03	Students will be able to sole turbulent problems using graphical methods.
8	**Compressible Flows:** Introduction and Definition, Limiting Condition of Compressibility, Speed of sound, Compressible flow in Nozzles, Subsonic, Supersonic and Hypersonic Flows, Mach Angle, Propagation of Small Disturbances, Formation of Shock, Shock Waves, Normal Shock Relations, Oblique Shock, Example Problems.	06	Students will be able to assess and analyse compressible flow problems.
Total		**39**	

Course Outcome	After completion of this course, students are expected to: • Derive and apply the conservation laws for fluid flow • Analyse different viscous flow phenomena like boundary layer, etc. • Understand and evaluate compressible flow problems • Develop analytical skills to solve complex flow problems

Learning Resources	Reference Books: 1. Fluid Mechanics by Pijush K.Kundu, IraM. Cohen, David R Dowling (Academic Press) 2. Advanced Engineering Fluid Mechanics by K. Muralidhar,Gautam Biswas, Narosa Publishing House, 1999. 3. Introduction to Fluid Mechanics and Fluid Machines, by S K Som, Gautam Biswas, S Chakraborty, Tata McGraw-Hill Education Pvt. Ltd. 4. Viscous Fluid Flow by Frank M White (McGraw-Hill) 5. Boundary Layer Theory by H Schllichting (McGraw-Hill)

Course Code	ME5121N	Course Name	Combustion Science & Technology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Thermodynamics	Co-requisite Courses	Nil	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	*Nil*

Course Objectives	The objective of the course is to introduce students with the following: • Application of combustion • Thermodynamic of combustion systems • Chemical kinetics • Theoretical analysis of premixed and diffusion flame • Combustion instability

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction to combustion: Applications of combustion, Various mode of combustion, Scope of combustion.	02	After completion of the module student will learn various modes of combustion, industrial and other application of combustion
II	Review of Thermodynamics: Thermodynamics properties, Laws of thermodynamics, Stoichiometry, Thermo-chemistry, adiabatic temperature, enthalpy of combustion and heating values, chemical equilibrium	05	Student will learn thermo chemistry, would be able to determine adiabatic flame temperature, chemical equilibrium.
III	Chemical kinetics. Reaction Kinetics, Global and Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism	06	Learn about chemical kinetics, single and multistep reactions
IV	Conservation equations for reacting flow: Fundamental laws of transport phenomena, Conservations Equations.	05	Student would be able to derive appropriate form of conservation equations for specific class of problems
V	Premixed Flame: One dimensional combustion wave, Laminar premixed flame, Burning velocity measurement methods, Effects of chemical and physical variables on Burning velocity, Flame extinction, Ignition, Flame stabilizations, Turbulent Premixed flame	08	Student will learn about different methods of flame speed predictions, theoretical determination of flame speed and influence of various parameters on flame speed.
VI	Diffusion Flame: Gaseous Jet diffusion flame, Liquid fuel combustion, Atomization, Spray Combustion, Solid fuel combustion	08	Students will learn about liquid fuel combustion, atomization process and atomizers
VII	Combustion and Emission: Atmosphere, Chemical Emission from combustion, Quantification of emission, Emission control methods	05	Will learn about Combustion emission and control
VIII	Introduction to turbulent premixed and diffusion flames , Combustion instabilities	05	Learn about turbulent combustion and its applications.

	Total	**42**	

Course Outcome	After completion of the course student will gather knowledge of fundamentals of combustion, thermo chemistry, chemical kinetics and theoretical modelling approaches which will help in gaining fast hand knowledge of any systems involving combustion process. The course will help to undergo advance studies and research in the pertaining field.

Learning Resources	**Reference Books:** 1. Principles of combustion by Kenneth K. Kuo, John Wiley, 2005 2. Combustion: Fundamentals and Application by Amitava Datta, Narosa Publishing House New Delhi/Alpha Science International Ltd. 3. Combustion Theory by F.A Williams, CRC Press

Course Code	ME5122N	Course Name	Design of Refrigeration and Air-Conditioning Systems	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Mechanical Engineering			Data Book / Codes/Standards	Refrigerant property tables

Course Objectives	The objective of the course is to cover: • The advanced vapour compression and vapour absorption refrigeration cycle • Design of main components used in vapour compression refrigeration cycle • Heating and cooling load calculation • Air conditioning system design

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Vapour compression refrigeration systems, multi-stage, flash chamber, cascade refrigeration system, dry ice production	6	• Students will learn about advanced refrigeration cycle • Theoretical analysis of refrigeration cycles with application
II	Vapour absorption cycle: Enthalpy concentration diagram. Low temperature refrigeration. Other refrigeration systems.	4	• Ammonia and LiBr based vapour absorption cycle analysis
III	Component design of vapour compression refrigeration system: Condenser, compressor, evaporator, expansion devices.	10	• Students would be able to design and analyse performance of compressor, condenser, evaporator, expansion devices
IV	Refrigerant properties. Ozone layer depletion and global warming	3	• Students will be able to choose type of Refrigerant for specific application.
V	Psychrometry of air-conditioning processes.	2	• Recapitulation of Psychrometry and air conditioning processes
VI	Air-conditioning: Human comfort, inside and outside design conditions. Solar heat gains in buildings, cooling load estimation. Humidity and temperature control. Air-conditioning system layout and calculations.	8	• Students will be able to calculate heating and cooling load for specific application, indoor and outdoor conditions
VII	Duct design. Transmission and distribution of air. Fan design.	6	• Would be able to design ducting systems
VIII	Heat pumps and their applications.	3	• Learn about heat pump and their applications
	Total	**42**	

Course Outcome	After completion of the course, student will be able to • Analyze advanced refrigeration cycles • Design and performance analysis of refrigeration and air conditioning system components • Ducting systems design

Learning Resources	1. Refrigeration and Air Conditioning, C. P. Arora, Tata McGraw-Hill 2. Refrigeration and Air Conditioning, G.S. Sawhney, Vayu Education of India

Course Code	ME5123N	Course Name	Gas Turbine and Jet Propulsion	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		**Data Book / Codes/Standards**	*Nil*

Course Objective	**CO1:** Gain in-depth knowledge of gas turbine and jet propulsion cycles, including component efficiencies and thermodynamic analysis. **CO2:** Understand the construction, working principles and performance of centrifugal and axial flow compressors. **CO3:** Analyse combustion systems in gas turbines, focusing on chamber design, efficiency and stability. **CO4:** Evaluate the operation and design of turbines, including work output, cooling, losses and efficiency. **CO5:** Learn techniques for matching gas turbine components for optimal operation under various design conditions.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Introduction to Gas Turbine Cycles: Ideal and actual cycles, Effects of re-heating, after cooling, multi-staging and heat exchanger, Isentropic and polytropic efficiency, Static and stagnation properties of gases	05	Understand ideal and actual gas turbine cycles and also evaluate the impact of re-heating, inter-cooling, and component efficiencies on performance.
2.	PrinciplesofJetPropulsion:Momentumthrust,Pressurethrust,Turbojet engine, Turbo prop-engine, Supersonic jets and ram jets, Turbofan engine	05	Understand the principles of jet propulsion and compare different types of jet engines based on thrust and operation.
3.	Centrifugal compressor: Elements of centrifugal compressor Flow through centrifugal compressors, Impeller and diffuser, Slipfactor, Compressibility effect, Loses in compressor, Centrifugal compressor characteristics, Surging and choking.	06	Understand the working principles, design parameters, and performance characteristics of centrifugal compressors.
4	Axial Flow Compressor: Elements of axial flow compressor, Principle of operation,Axialcompressorstages,Factorsaffectingstagepressureratio, Work done factor, Degree of reaction, Losses and efficiency, Off designperformance,Singleandmultistagecompressorcharacteristics,Three dimensional flow, Radial equilibrium theory	07	Understand the working principles, design parameters, and performance characteristics of axial flow compressors.
5.	Combustion: Types of combustion chamber, Combustion mechanism and important	05	Understand combustion mechanisms, chamber types and

	combustion parameters, Design of combustion system and design parameters. Pressure loss, Combustion efficiency, Combustion stability, Fuel-air ratio, Fuel injection system.		key design parameters affecting combustion efficiency and stability.
6.	Turbine: Introduction, Two-dimensional cascade analysis, Work done, Degree of reaction, Losses and efficiency. Multi-staging of Turbine, Vortex flow theory, Turbine cooling	06	Analyse turbine operation, work output, efficiency and cooling techniques using cascade and vortex flow theories.
7.	Matching of Components: Dimensional analysis for component matching, Engine design point operations, Engine off design operations, Engine operating lines	05	Understand the matching of gas turbine components under design and off-design conditions using dimensional analysis.
Total		**39**	

Course Outcome	This course enables students to understand and analyze the complete working of gas turbines and jet propulsion systems, including all major components—compressors, combustors and turbines. It provides the skills to evaluate system performance, optimize design and handle off-design conditions effectively.

Learning Resources	**Text Books:** 1. Saravana muttoo, H. I. H., RogersG .F. C., Cohen H., Gas Turbine Theory, 2001, Pearson 2. Bathie W. W. Fundamentals of Gas Turbines, Second Edition, John Wiley & Sons Inc. **Reference Books:** 1. S. M. Yahya, Turbines, Compressors and Fans, Fourth Edition, 2011,Tata McGraw-Hill Education Pvt. Ltd.

Course Code	ME5124N	Course Name	Greenhouse Technology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	*Nil*

Course Objective	1. Overview of greenhouse technology, history global scenario. 2. Understanding of different types of GH and their constructions. 3. GH microclimate, various energy interactions and energy balances. 4. Applications in protected cultivation. 5. Economic of GH production

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	**Introduction:** History and types of greenhouse; importance, function and features of greenhouse; scope and development of greenhouse technology. Location, Planning and various component of greenhouse.	07	Overview of the technology, history and types.
2.	**Construction of Greenhouse** Design criteria and calculation; constructional material and methods of construction; covering materials and its characteristics, solar heat transfer, solar fraction for green house, steady state analysis of green house.	07	Construction of different types
3.	**Greenhouse Microclimate** Greenhouse heating, cooling, shedding and ventilation systems; Carbon Dioxide generation and monitoring and lighting systems, instrumentation & computerized environmental Control Systems.	07	Understanding the microclimate of GH and associated energy interactions
4	**Nutrition and Plant growth** Watering, fertilization, root substrate and its pasteurization, containers and benches, plant nutrition; Plant growth and development; Alternative cropping systems; plant tissue culture, chemical growth regulation; disease control; integrated pest management; post production quality and handling Cost analysis of greenhouse production.	07	Knowledge of plantation and its nutritional requirements
5.	**Applications** Applications of green house & its repair & maintenance; Fundamental principles of vegetable production and commercial production of vegetable crops as well as marketing of horticulture products.	07	Knowledge about applications of GH
6.	**Cost analysis** Cost of production, market economics, growth rate, pay-back analysis	04	Understanding the economics of GH cultivation
Total		**39**	

Course Outcome	Gaining an overview of greenhouse technology, history global scenario and in-dept understanding of different types of GH, microclimate and various energy interactions of GH, applications of GH in protected cultivation and associated economics.

Learning Resources	**Text Books:** 1. Greenhouse Technology for Controlled Environment. G.N. Tiwari; Alpha Science, 2003 - Technology& Engineering 2. Greenhouse Technology. Arupratan Ghosh; New India Publishing Agency. Technology &Engineering. Protected Cultivation of Vegetable Crops. Balraj Singh, Kalyani Publishers.

Course Code	ME5125N	Course Name	Energy, Environment & Economics	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	1. Understanding of the global energy scenario. 2. Understanding environmental impacts of different resources and technologies. 3. Understanding and ability to analyze economics and policies related to energy technologies 4. Concepts of LCA and sustainability.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Global Trends in Energy Use, Energy Flow Diagram, Emission Factor, Energy & Quality of Life, Energy Inequality, Energy Demands, Energy Security.	06	Knowing energy perspectives.
2.	Issues with Conventional Energy Resources: Resource Depletion, Environmental Impacts, Renewable Energy Sources, Resource Distribution, Energy Mix, Challenges.	06	Resources and their impacts on environment
3.	Energy & Environment, Effect of Pollutants, Climate Change & Global Warming, Mitigating Challenges; Frameworks of Action: Ethics	06	Impacts of energy technologies
4	Energy Economics: Economics of electricity supply and renewable energy and related policies. Time value of money; Simple and discounted payback period, Net present values, Internal rate of internal; cost-benefit analysis; Levelised costs, Variable and fixed costs; Costing for environment impacts; Environmental damage cost and cost benefit due to carbon capture;	08	Understanding economic issues and costing
5.	Techno-economic and exergo-economic assessments; exergo-environmental assessment, Life Cycle Assessment, Cost of Carbon Emission, Carbon Credits	07	Understanding exergo economics and LCA
6.	Sustainability, Energy Policy, Global and local initiatives	06	Understanding sustainability and policy issues
Total		**39**	

Course Outcome	Understanding of the global energy scenario, environmental impacts of different resources and technologies; In-depth understanding of techno-economic, exergo-ecomic analysis, LCA as well as understanding of associated economic and policies related to issues and the concept of sustainability.

Learning Resources	**Text Books:** 1. Energy and the Environment, 4th Edition, Robert A. Ristinen, Jack J. Kraushaar, Jeffrey T. Brack, Wiley 2. Energy Economics and Policy, James M. Griffin, Henry B. Steele, 2nd Edition 1986. 3. Energy Economics: Science, Policy, and Economic Applications, Thomas R. Sadler, Rowman & Littlefield **Reference Books:** 1. Handbook of Energy and Environment in the 21st Century, Technology and Policy Dynamics, Edited By Muhammad Asif, Guller Sahin, Muhammad Khalid, Routledge, 2024 2. Industrial Ecology and Sustainable Engineering (2009) by T. E. Graedel, Braden Allenby

Course Code	ME5126N	Course Name	Nuclear Power Engineering	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		Mechanical Engineering		Data Book / Codes/Standards	*Nil*

Course Objective	1. Understand the basic principles of nuclear physics and the operational principles of different nuclear reactors. 2. Assess the potential environmental impacts of nuclear power, including radioactive waste generation, thermal discharge, and carbon emissions 3. Describe the nuclear fuel cycle, from mining and enrichment to fuel fabrication, in-reactor behavior, and spent fuel management (reprocessing, disposal). 4. **Identify and explain the key safety principles and regulations** governing the design, construction, and operation of nuclear power plants.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	**Nuclear Reactions** Mechanism of Nuclear Fission- Nuclides- Radioactivity- Decay Chains- Neutron Reactions- The Fission Process- Reactors- Types of Fast Breeding- Reactor- Design and Construction of Nuclear reactors-Heat Transfer Techniques in Nuclear Reactors-Reactor Shielding.	07	Understand the basic principles of nuclear physics and nuclear reactors
2.	**Reactor Materials** Nuclear Fuel Cycles- Characteristics of Nuclear Fuels- Uranium- Production and Purification of Uranium- Conversion to UF4 and UF 6 - Other Fuels like Zirconium, Thorium and Berylium.	07	Gain knowledge of nuclear fuel materials
3.	**Reprocessing** Nuclear Fuel Cycles -Spent Fuel Characteristics - Role of Solvent Extraction in Reprocessing Solvent Extraction Equipment.	07	Gain knowledge of nuclear fuel cycles
4	**Separation of Reactor Products** Processes to be Considered – 'Fuel Element' Dissolution – Precipitation Process – Ion Exchange Redox – Purex – TTA- Chelation–U235 – Hexone– TBP and Thorax Processes–Oxidative Slaging and Electro – Refining – Isotopes – Principles of Isotope Separation.	07	Understand the operational principles of reactors
5.	**Waste Disposal and Radiation Protection** Types of Nuclear Wastes – Safety Control and Pollution Control and Abatement – International Convention on Safety Aspects – Radiation Hazards Prevention.	07	Gain knowledge about waste disposal and radiation protection

6.	**Environment & Cost analysis** Environmental impact, Accident history, Cost of construction and production, pay-back analysis	04	Understand the environmental impact of nuclear power generation
Total		**39**	

Course Outcome	1. Understand the basic principles of nuclear physics and the operational principles of different nuclear reactors. 2. Assess the potential environmental impacts of nuclear power, including radioactive waste generation, thermal discharge, and carbon emissions 3. Describe the nuclear fuel cycle, from mining and enrichment to fuel fabrication, in-reactor behavior, and spent fuel management (reprocessing, disposal). 4. Identify and explain the key safety principles and regulations governing the design, construction, and operation of nuclear power plants.

Learning Resources	**Text Books:** 1. ThomasJ.Cannoly,"FundamentalsofnuclearEngineering"JohnWiley1978 2. CollierJ. G., and HewittG.F, "Introduction to Nuclear power", Hemisphere Publishing, New York, 1987. 3. “NuclearEnergy-AnIntroductiontoConcepts,SystemsandApplicationsofNuclearProcess”by Raymond L. Murray, published by Butterworth Heinemann, 2001 4. “Introduction to Nuclear Engineering” 3rd ed., by J.R. Lamarsh and A. J. Baratta, published by Prentice Hall, 2001 5. “The Future of Nuclear Power-An Interdisciplinary MIT Study”,2003

Course Code	ME5161N	Course Name	Renewable & Alternative Energy Technologies	Course Category	OE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		**Data Book / Codes/Standards**	*Nil*

Course Objective	**CO1:** Analyse conventional power systems and recognize the need for cleaner energy solutions and renewable integration. **CO2:** Gain in-depth knowledge of solar, wind, fuel cells and other renewable technologies for electricity generation. **CO3:** Evaluate hybrid and advanced systems such as MHD, thermoelectric and biomass-based power generation for efficient energy use. **CO4:** Understand energy storage, conversion, and grid balancing techniques such as pumped hydro and BIGCC systems. **CO5:** Assess energy economics, environmental impacts, and relevant policies to support sustainable energy development.

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Introduction: Perspective, Environmental impacts of conventional power plants, Advanced technologies for cleaner power from fossil fuels, Renewable energy sources	03	Understand the environmental impacts of conventional energy systems and explore advanced clean technologies and renewable sources.
02	Solar Power: Solar geometry, radiation on inclined surfaces and tilt factors, Solar Photovoltaic (SPV) - Semiconductors & junctions, working principles, descriptions, I-V characteristics, efficiency and fill factor. Solar thermal power generation - plants based on parabolic trough and dish collectors, solar tower power plants, solar chimney plant	05	Learn solar energy fundamentals including solar geometry, PV systems and solar thermal power plant technologies.
03	Fuel Cells:- Introduction, descriptions and classification, Working principles, electrochemistry of H_2-O_2 cells, Nernst eqn. and e.m.f., Over potentials and I-V characteristics, voltage and efficiency calculations, PEM fuel cells: cell and stack constructions, fuels and fuel reformer, applications; High temperature cells (MCFC and SOFC): cell and stack constructions, fuels, internal reforming, applications	05	Understand the working principles, classifications and applications of various fuel cell technologies.
04	Magneto Hydro Dynamic (MHD) power generation - Working principle of MHD, descriptions and classification, e.m.f., current density and power calculations (Faraday & Hall configurations), applications	04	Understand the basics of MHD power generation and calculate power output using Faraday and Hall configurations.
05	Thermoelectric devices - Working principles, descriptions, emf and figure of merit, efficiency	09	Learn the principles of thermoelectric devices, biomass

	calculations. Biomass energy conversion: Bio-gasification, gas engines, biomass gasification combined cycles (BIGCC). Pumped hydro plants: Principle of operation, Load fluctuations and load leveling, load curve analysis		energy conversion and pumped hydro storage systems.
06	Wind Energy Conversion. Principle of conversion, Types of turbines. Tidal, Wave and Ocean Thermal (OTEC) energy conversion: Basic principles, Description of different types of plants, open and closed OTEC systems Geo-thermal energy - Principle of Conversion, geothermal resources, classification of plants.	09	Explore the principles, types and operational details of wind, tidal, wave, ocean thermal and geothermal energy systems.
07	Economics and policies of non-renewable energy, environmental assessment, Carbon credit	04	Evaluate the economic feasibility, environmental assessment and policy implications related to non-renewable and renewable energy sources.
Total		**39**	

Course Outcome	This course provides a comprehensive overview of both conventional and renewable power generation technologies with a strong emphasis on environmental sustainability and technological advancement. Students will gain the skills to analyse, compare and evaluate different energy systems and their impact on the environment and economy.

Learning Resources	**Reference Books:** 1. Principles of Energy Conversion - Culp 2. Non-Conventional Energy - B H Khan 3. Solar Energy by S P Sukhatme 4. Fuel Cell Systems Explained – Larminie & Dick

Course Code	ME5201N	Course Name	Hydrogen Energy & Fuel Cells	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	**CO1:** Understand hydrogen's thermodynamic behaviour and its absorption, desorption and storage mechanisms. **CO2:** Learn various hydrogen production, purification and storage techniques. **CO3:** Gain knowledge of various fuel cell types, their operating principles, components, system design and applications. **CO4:** Assess the role of hydrogen in transportation, aviation and power systems, along with related safety protocols. **CO5:** Evaluate economic, environmental and policy dimensions of hydrogen technologies for sustainable energy planning.

Module	Syllabus	Duration (class-hour)	Module Outcome
Thermodynamics of Hydrogen	Thermodynamic properties of Hydrogen, Gibbs phase rule, Pressure-Concentration-Temperature (P-C-T) plots, Van't Hoff plot for absorption and desorption enthalpies, Gravimetric capacities, Joule-Thomson effect, Non-ideal treatment of hydrogen gas, Hydrogen absorption/desorption: chemisorptions, nucleation and growth, diffusion), kinetics models, estimation of activation energy, Hydrogen adsorption isotherms	05	Understand thermodynamic properties of hydrogen and absorption/ desorption mechanisms including
Production & Separation	Methods of hydrogen production: chemical, thermos-chemical, electrolytic, direct solar water splitting, biological, Hydrogen separation and purification (Pressure swing adsorption, solvent based absorption, membrane separation and cryogenic separation etc.)	05	Gain knowledge of various hydrogen production methods
Purification and Storage	Purification and storage, Types of storage, Materials for storage: metal hydrides, high surface area materials, complex and chemical hydrides, storage issues for mobile units (volumetric and gravimetric energy density considerations for storage).	05	Understand hydrogen storage methods, materials used and challenges related to mobile storage systems.
Overview of Fuel Cells	Electrochemical conversion and Fuel Cells, History, Classification, Work Potential, Reversible Voltage, Nernst Equation, Irreversibilities–Activation Ohmic and Concentration over potentials; Fuel Crossover and Internal Currents, Thermal and Mass Balances, Efficiency and fuel utilization.	05	Learn the principles of electrochemical conversion and the fundamentals of different types of fuel cells.
Different types of	Proton Exchange Membrane Fuel Cells: Polymer Electrolyte; Electrodes, MEA, Bipolar Plate and fuel cell stacks; Water Management; Cell Cooling and	10	Understand the construction, operation, and system

Fuel Cell	Air Supply; Systems and applications. Alkaline Electrolyte Fuel Cells: Construction and operating principle, Operating Pressure and Temperature, Electrodes, Cell Interconnections, Current status and applications. Direct Methanol Fuel Cells: Anode Reaction and Catalysts; Electrolyte and Fuel Crossover; Cathode Reactions and Catalysts; Methanol Production, Storage, and Safety; Applications Solid oxide fuel cell (SOFC): Construction and operating principle; Components, Design and Stacking Arrangements; Performance, Systems and applications Molten carbonate fuel cell (MCFC) Construction and operating principle; Components, Design and Stacking; CO2 transport and recycling; Performance, Systems and applications.		design of Fuel cell.
Reversible Fuel Cells	Principle of operation, types, performance and efficiency, systems and applications.	03	Under the basics of Reversible Fuel cell
Hydrogen and fuel cells for Transportation	Hydrogen combustion engines and fuel cells for transportation, Hydrogen in aviation, Safety issues for Hydrogen: Types of hazards, accident history, safety guidelines.	04	Explore the role of hydrogen combustion and fuel cells in transportation and aviation, along with safety considerations.
Economics & Environmental Impacts	Economics of Hydrogen and fuel cells, LCA, Emission reduction potential and environmental assessment, Policy issues.	03	Analyse the economics, environmental impact and policy frameworks of hydrogen technologies.
Total		**40**	

Course Outcome	This course provides a comprehensive understanding of hydrogen as an energy carrier, covering its production, storage, conversion and utilization technologies. It enables students to evaluate the technical, environmental and economic aspects of hydrogen and fuel cell systems for real-world applications.

Learning Resources	**Text Books:** 1. Advances in Hydrogen Production, Storage and Distribution, Angelo Basile, Adolfo Iulianelli,1st Edition, Woodhead Publishers, Cambridge (UK), 2014 2. Hydrogen and Fuel Cells: Emerging Technologies and Applications; Bent Sorensen, Giuseppe Spazzafumo; 3rd Edition, 2018. 3. Fuel Cell Systems Explained, James Larminie, Andrew Dicks, 2nd Edition,Wiley 4. Fuel cell fundamentals, ryano'hayre, suk-woncha, whitneyg. Colella, fritzb. Prinz, 3rd Edition, Wiley 5. "The Future of Nuclear Power- An Inter disciplinary MIT Study", 2003

	Reference Books 1. Handbook of Hydrogen Energy, Edited By S.A. Sherif, D. Yogi Goswami, E.K. (Lee) Stefanakos, Aldo Steinfeld, Elsevier, 2014 2. Michael Hirscher, Hand Book of Hydrogen Storage, 1st Edition, Wiley-VCN Verlag GmbH, 2010. 3. Fuel Cell Handbook, US DoE, 7th Edition, 2004 (available online at DoE NETL) 4. Gavin Walker, Solid State Hydrogen Storage: Materials and Chemistry, 1st Edition,Woodhead Publishers, Cambridge (UK), 2008. 5. Recent Trends in Fuel Cell Science and Technology, S.Basu,1stEdition, Springer 6. Introduction to Hydrogen Technology, 2nd Edition, K. S. V. Santhanam, Roman J. Press, Massoud J. Miri, Alla V. Bailey, Gerald A. Takacs, Wiley, 2017 7. Rober A. Varin, Tomasz Czujko, Zbigniew S. Wronski, Fuel Cells and Hydrogen Energy Series: Nanomaterials for Solid State Hydrogen storage, 1st Edition, Springer, 2009

Course Code	ME5202N	Course Name	Advanced Energy Storage Systems	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	
	• The objective of this course is to provide students with fundamental and advanced knowledge of various energy storage technologies with their applications. • The course aims to develop a comprehensive understanding of both the conventional methods of energy storage along with the modern state of the art technologies. • The students can learn to integrate the appropriate methods of energy storage for various renewable energy based systems for sustainable development.

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Basics of energy storage, requirement and background. Electrical energy storage system- Battery types, Lead Acid battery, Nickel Cadmium, Sodium Sulphur and Lithium ion battery, Maintenance free battery, Battery charging and discharging, Battery parameters, Metal air batteries, Designer's choice of battery, ultra and super capacitor	06	Understanding the types of electrical energy storage devices.
02	Hydraulic Energy Storage, Site selection for storage type hydro-electric plants, Hydrograph, flow duration curve, mass curve, Dams and types of Dam, spillways, Run off river plant, Pump Storage plant, merits and demerits	04	Learn the basics of different types of storage type hydel plants along with the site selection and components.
03	Super conducting Magnetic Energy Storage (SMES)	03	To learn the basics of SMES systems.
04	Mechanical energy storage device- flywheel system and applications, compressed air storage system, types and applications.	05	Understanding the various mechanical energy storage system like CAES and flywheel energy storage.
05	Chemical Energy storage- Bio-fuels and Hydrated Salts, Accumulators with internal and external storage. Graphene based composites for electrochemical energy storage	05	Develop the knowledge of chemical energy storage systems
06	Hydrogen energy storage, methods and modifications in the existing infrastructure for the hydrogen storage. Fuel cell system. Fuel cell types and thermodynamics, efficiency and voltage.	05	Understanding the methods of hydrogen storage and fuel cells.
07	Thermal Energy Storage System- Sensible heat storage system, Latent heat storage system, Thermo-chemical energy storage. Solar Pond and types.	03	Understanding the basics of types of thermal energy storage system and applications
08	Basics of Thermo-electric generator. Heat Pipes and Vapour Chambers.	03	Basic knowledge on the working principle of thermo-electric generator, heat pipes and applications

09	Economics of the Energy Storage	05	To familiarize with the terminologies related to the economics of energy storage for various applications.
Total		**39**	

Course Outcome	● From this course, the students will be able to understand the working principles of various forms of storage of energy. ● This is very important for ensuring the energy availability round the clock even for the remote areas, where extension of the conventional grid electricity is a challenge. ● The students will gain the ability to apply theoretical and practical knowledge to solve engineering problems related to energy storage for the various real life applications.

Learning Resources	**Text books:** 1. Energy Storage Systems by David Elliott, IOP Publishing Ltd. Bristol, UK, 2017.ISBN 978-0-7503-1531-9 (ebook). 2. Solar Energy: Principles of Thermal Collection and Storage by S. P. Sukhatme and J.K.Nayak, Tata Mc Graw-Hill Publishing Company Limited, New Delhi. **Reference Books:** 1. Fuel Cell Handbook (Seventh Edition) US Department of Energy by EG & G Technical Services, Inc. November 2004. 2. Solar Engineering of Thermal Processes by John A Duffie and William A Beckman, John Wiley & Sons, Inc. First published April 2013, Print ISBN: 9780470873663 |Online ISBN:9781118671603. 3. Storing Energy Ist Edition by Trevor Letcher, Imprint Elsevier, 2016, Hardcover ISBN: 9780128034408,eBook ISBN: 9780128034491.

Course Code	ME5203N	Course Name	Advanced Heat Transfer	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The course will enable students to: • Understand each term of the energy conservation equation and apply them to formulate conduction, convection and radiation heat transfer. • Develop analytical skills to solve conduction equation • Apply scaling laws and similarity techniques to convection problems • Understand and evaluate radiation problems in participating media

Module	Syllabus	Duration (class-hour)	Module Outcome
	CONDUCTION		
1.	1D Steady State Heat Conduction: Bessel Differential Equations and Bessel Functions, Equi-dimensional (Euler) Equation, Graphically Presented Solutions to Fin Heat Transfer Rate, Moving Fins and its Application, Variable Area Fins.	03	Students will be able to analytically solve 1D heat conduction
2.	2D Steady State Heat conduction: Sturm-Liouville Boundary Value problems: Orthogonality, Procedure for the Application of Separation of Variables Method, Integrals of Bessel Functions, Non-homogeneous Differential Equations, Non-homogeneous Boundary Conditions: The Method of Superposition.	04	Students will be able to analytically solve 2D heat conduction
3.	Transient Conduction: Transient Conduction in Plates, Non-Homogeneous Equations and Boundary Conditions, Transient Conduction in Cylinders and Spheres, Time Dependent Boundary Conditions: Duhamel's Superposition Integral, Formulation of Duhamel's Integral, Extension to Discontinuous Boundary Conditions, Applications, Conduction in Semi-Infinite Regions: The Similarity Transformation Method.	04	Students will be able to analytically and graphically solve unsteady 1D heat conduction
4.	Non-Linear Conduction Problems: Sources of Non-Linearity, Taylor Series Method, Kirchhoff and Boltzmann Transformation and their Combining, Exact Solutions, Approximate Solutions: The Integral Method: Procedure and Accuracy of the Integral Method, Application to Cartesian and Cylindrical Coordinates, Non-Linear Problems, Energy Generation, Perturbation Solutions: Solution Procedure, Examples and Perturbation solutions.	04	Students will be able to analytically solve non-linear conduction problems.
	RADIATION		
5.	Introduction: Radiation characteristics of opaque surfaces, solids, liquids and gases. Radiation equation. Radiation transfer theory.	02	Students will be able to understand and formulate radiation

			problems
6.	Radiative property prediction from electromagnetic wave theory: macroscopic Maxwell equations, electromagnetic wave propagation in unbounded media, polarization, reflection and transmission, theories for optical constants.	03	Students will be able to connect radiation to electromagnetic wave theory
7.	Radiative properties of real surfaces and view factors: Crossed- Strings method, inside sphere method and unit sphere method.	02	Students will be able to understand and calculate view factor
8.	Radiative exchange between gray, diffuse surfaces. Radiative exchange between partially specular gray surfaces. Radiative exchange between non-ideal surfaces. The Monte Carlo method for surface exchange. Surface radiative exchange in the presence of conduction and convection.	04	Students will be able to analyze and evaluate radiation heat exchange between surfaces
9.	Radiative transfer equation in participating media (RTE). Radiative properties of molecular gases, particulate media and semi-transparent media.	02	Students will be able to understand and assess radiation in participating medium
CONVECTION			
11.	Equations of continuity, motion, energy and mass diffusion	01	Students will be able to formulate convection problems
13.	Laminar heat transfer in ducts Turbulent flow in ducts	03	Students will be able to formulate and evaluate convection in ducts
14.	Laminar boundary layers Integral methods Turbulent boundary layers	03	Students will be able to formulate boundary layer problems
19.	Natural convection	02	Students will understand, formulate and solve natural convection problems
20.	Boiling Condensation	02	Students will be able to evaluate and assess phase change phenomena
TOTAL		**39**	

Course Outcome	After completion of course, students are expected to: • Understand each term of the energy conservation equation and apply them to formulate conduction, convection and radiation heat transfer. • Develop analytical skills to solve conduction equation • Apply scaling laws and similarity techniques to convection problems • Understand and evaluate radiation problems in participating media • Analyse phase change heat transfer phenomena

Learning Resources	**Text Books:** 1. Heat Conduction by L.M. Jiji, Springer 2. Heat Conduction by Y. Yener and S. Kakac, Taylor and Francis 3. Heat Conduction by D.W. Bahn, John Wiley & Sons 4. Radiative Heat Transfer by M. F. Modest, Elsevier (Academic Press) 5. Thermal Radiation Heat Transfer by J. R. Howell, R. Siegel and M.P. Menguc, CRC Press, Taylor and Francis 6. Radiative Transfer by H.C. Hottel and A.F. Sarofim, McGraw-Hill. 7. Convective Heat Transfer by L.C. Burmeister, John Wiley & Son 8. Convective Heat Transfer by A. Bejan, John Wiley & Son 9. Convective Heat and Mass Transfer by S.M. Ghiaasiaan, Cambridge University Press

Course Code	ME5221N	Course Name	Numerical Heat Transfer and Fluid Flow	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Fluid Mechanics	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	Mechanical Engineering	Data Book / Codes/Standards	*Nil*		

Course Objective	By the end of this course, students will be able to: • Explain the physical meanings of governing equations of fluid flow and heat transfer • Understand various discretization methods used in CFD. • Solve steady and unsteady heat conduction problems using numerical methods • Implement various discretization schemes in case of convection and diffusion processes • Understand the challenges in flow field computation • Apply algorithms like SIMPLE and SIMPLER for pressure-velocity coupling. • Gather basic knowledge about the use and capabilities of commercial CFD software

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Introduction; Governing differential equations: Meaning of a differential equation, continuity equation, momentum equation, energy equation, nature of coordinates	06	Understand the governing equations for mass, moment and energy in different co-ordinate systems
02	Discretization methods: Taylor series formulation, variational formulation, method of weighted residuals, control volume formulation, four basic rules	06	Should be able to apply different methods to discretize the governing equations
03	Heat conduction: Basic equations for steady 1-D conduction, grid spacing, interface conductivity, nonlinearity, source term linearization, boundary conditions, solution of linear algebraic equations, unsteady one dimensional conduction, two and three dimensional situations, over relaxation and under relaxation, some geometric considerations	07	Formulate and solve the 1D diffusion equation with different boundary conditions
04	Convection and diffusion: Basic equations for steady 1-D convection and diffusion, upwind scheme, exact solution, exponential scheme, hybrid scheme, power law scheme, generalized formulation, consequences of various schemes, dicretization equation for two dimensions, dicretization equation for three dimensions	08	Student should be able to formulate and solve the 1D convection-diffusion problem Able to evaluate various discretization schemes, and formulate generalized equations for 2D and 3D problems
05	Computation of flow field: Some related difficulties, representation of pressure gradient term, representation of continuity equation, a remedy by staggered grid,	07	Understand and apply different algorithms such as SIMPLE and

	corresponding momentum equations, pressur and velocity corrections, pressure correction equation, SIMPLE algorithm, SIMPLER algorithm.		SIMPLER to solve the fluid flow and heat transfer equations
06	Introduction to commercial CFD codes.	05	Familiarize with commercial CFD codes
Total		**39**	

Course Outcome	CO1: Understand governing equations used in fluid flow and heat transfer. CO2: Apply different discretization methods needed for numerical modeling. CO3: Solve numerically steady and unsteady heat conduction problems CO4: Analyze convection–diffusion problems using different numerical schemes. CO5: Compute flow and temperature fields using SIMPLE and SIMPLER algorithms. CP6: Gain exposure to use commercial CFD software.

Learning Resources	**Text Books:** 1. An Introduction to Computational Fluid Dynamics: The Finite Volume Method by H. K. Versteeg and W. Malalasekera. 2. Numerical Heat transfer and Fluid Flow by Suhas V. Patankar. 3. Computational Fluid Dynamics: The Basics with Applications by John D. Anderson, Jr. **Reference Books:** 1. Computational Fluid Mechanics and Heat Transfer by Dale A. Anderson, John C. Tannehill, Richard H. Pletcher. 2. Computational Fluid Dynamics: Principles and Applications by J. Blazek. 3. Computational Fluid Dynamics for Engineers by TuncerCebeci, Jian P. Shao, FassiKafyeke, Eric Laurendeau.

Course Code	ME5222N	Course Name	Energy Efficient Buildings	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		Mechanical Engineering		Data Book / Codes/Standards	*Nil*

Course Objective	❖ Understand the interaction between solar radiation, building orientation and design for energy-efficient architecture. ❖ Learn various passive heating, cooling and daylighting strategies applicable to different climates. ❖ Develop thermal models and analyse heat transfer in buildings for performance improvement. ❖ Explore Zero Energy Building concepts, green building ratings and energy management practices. ❖ Apply simulation and auditing techniques to evaluate and enhance building energy performance.

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Solar radiation concept and the Sun earth geometry	04	Understand the fundamentals of solar radiation
02	Building Orientation and design	04	Learn the principles of building orientation and design
03	Concept of passive heating and cooling in the buildings	04	Understand passive heating and cooling used in building design
04	Basics of heat transfer in buildings. Thermal modelling of the passive concepts	06	Learn basic heat transfer concepts and thermal modelling techniques for passive energy concepts in buildings.
05	Evaporative cooling and methods. Day lighting through windows. Earth air tunnel and heat exchanger	08	Understand evaporative cooling methods, daylight utilization, and earth-air heat exchange techniques
06	Zero energy Building concepts, practices and rating system. Design of Green Building and energy management of buildings	05	Explore the concept and design principles of Zero Energy Buildings and green building rating systems.
07	Energy Auditing and Radiation Cooling of Building in hot and Dry Climate	04	Understand building energy auditing techniques and radiation cooling practices for hot and dry climates.
08	Simulation Techniques of Energy Conservation in Building	04	Learn about simulation tools to design energy efficient buildings
Total		**39**	

Course Outcome	• This course provides comprehensive knowledge of passive and active energy-efficient building design strategies, integrating solar geometry, thermal modeling and green building concepts. • Students will gain practical skills in auditing, simulation and sustainable building practices.

Learning Resources	**Text Books:** 1. Energy Conservation in Buildings by O.P.Jakhar, Khanna Publishing House, 2023 First Edition New Delhi, India. 2. Energy efficient buildings in India by MilliMajumdar Teri Press ISBN 9788185419824. 3. Energy Conservation Guidebook 2nd Edition by Dale R Patrick, Stephen W. Fardo, Ray E. Richardson and Steven R. Patrick published by The Fairmont Press Inc. USA distributed by CRC Press (Taylor and Francis Group) 2007. **Reference Books:** 1. Handbook of Energy Efficiency in Buildings A life Cycle Approach edited by Francesco Asdrubali, Umberto Desideri, 2018, Elsevier, ISBN 978-0-12-812817-6. 2. Energy Conservation Building Code 2017 (with amendments up to 2020) published by the Bureau of Energy Efficiency, Government of India, Ministry of Power New Delhi.

Course Code	ME5223N	Course Name	Cryogenic Systems and Equipment	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		Mechanical Engineering		Data Book / Codes/Standards	*Nil*

Course Objective	• To have idea about cryogenic systems, • To understand the behaviour and properties of cryogenic fluids and materials at very low temperatures. • To analyze various gas liquefaction cycles and their performances • To study different cryogenic refrigeration techniques including magnetic refrigerator • To acquire sufficient knowledge on the storage and safe handling of cryogenic fluids along with different insulation methods under cryogenic conditions. • To know about vacuum technology fundamentals. • To identify the role of cryogenics in modern applications such as space technology, superconductivity, metallurgy, and medical science.

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Introduction: Introduction to Cryogenic Systems: Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures.	06	• Understand the properties of cryogenic fluids and different materials at low temperatures
02	Gas Liquifaction cycles: Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve - Joule Thomson Effect. Liquefaction Cycles: Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claudes Cycle, Collins Cycle, Dual Pressure Cycle, Helium Refrigerated Hydrogen Liquefaction Systems.	09	• Should understand the basic principles of gas liquefaction. • Compare liquefaction cycles and evaluate performances in terms of F.O.M. and yield.
03	Critical components in Liquefaction Systems, Introduction to air separation.	03	• Should be able to understand key components of liquefaction systems •
04	Cryogenic Refrigerators: J.T. Cryocoolers, Stirling Cycle Refrigerators, G.M. Cryocoolers, Pulse Tube Refrigerators, Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators Storage and transfer of Cryogenic liquids, Design of storage vessels.	07	• Understand the working of various cryogenic refrigerators • Should know about storage, transfer and design of cryogenic vessels
05	Cryogenic Insulation: Cryogenic Insulation, Multi-layer insulation, Vacuum insulation etc. Applications: Applications of Cryogenic in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications, space simulation.	07	• Understand types of cryogenic insulation and their applications. • Identify various cryogenic applications in space, metallurgy and medicine.

06	Vacuum Technology: Basic Theory, Gas surface interactions: physisorption, chemi-sorption, condensation, Vacuum Pumps, Vacuum Applications: Freeze drying, packaging, vacuum coating, microelectronics, particle accelerators, distillation, metallurgical processes, television and X-ray tubes,	07	• Understand the basics of vacuum technology and gas-surface interactions. • Explain the working of vacuum pumps and identify major industrial and scientific applications.
Total		**39**	

Course Outcome	CO1: Understand the properties of cryogenic fluids and material behaviour at very low temperatures CO2: Analyze various gas liquefaction cycles and evaluate their performance. CO3: Identify critical components in liquefaction systems CO4: Explain the working principles of different cryogenic refrigerators CO5: Understand methods of storage, transfer, and insulation of cryo-fluids. CO6: Recognize the role of cryogenics in practical applications including space, medicine, superconductivity, and metallurgy. CO7: Understand the basics of vacuum technology, gas-surface interactions, and industrial applications of vacuum systems.

Learning Resources	**Text Books:** 1. Cryogenic Systems, R.F. Barron, McGrawHill, 1985. 2. Cryogenic Process Engineering, K.D. Timmerhaus and T.M. Flynn, Plenum Press, 1989 3. Fundamentals of Cryogenic Engineering, M Mukhopadhyay, PHILearning Pvt. Ltd., NewDlehi, 2010 **Reference Books:** 1. Cryogenic Engineering, R.B.Scott, Van Nostrand and Co.,1962 2. Vacuum Science and Technology, V.V. Rao, T.B. Ghosh, K.L. Chopra, Allied Publishers Ltd., New Delhi. 3. Vacuum Technology, A. Roth, North Holland Publishing Company, Amsterdam

Course Code	ME5224N	Course Name	Clean Coal Technology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		Mechanical Engineering		Data Book / Codes/Standards	*Nil*

Course Objective	1. Understanding of the prospect of coal as energy resources 2. Understanding of advanced and clean coal technologies 3. Understanding of environmental impacts of conventional coal combustion 4. Understanding of Carbon mitigation potential of clean coal technologies 5. Overview of Carbon capture technologies

Module	Syllabus	Duration (class-hour)	Module Outcome
01	**Coal as Fuel** Coal properties, resources, mining and environment impacts of mining, Coal for power generation (conventional) and its environment impact, Coal gasification, Gas cleaning systems and environmental issues	07	Understanding of the prospect of coal as energy resources
02	**Advanced Coal Energy Systems** Super Critical Power cycles, Principles of Waste Heat Recovery and Co-Generation, Analysis of Heat Recovery Systems, Regenerators & Recuperators for waste Heat Recovery, Condensate and Back Pressure Steam Turbines, Design of Waste Heat Recovery Boilers, Combined Cycle Power Plants based on waste Heat Recovery, Fluidized Bed Combustion, Atmospheric Fluidized Bed Combustion (AFBC), Pressurized Fluidized Bed Combustion (PFBC) and Circulating Fluidized Bed Combustion (CFBC), Clean Coal Technologies- gasification, Integrated Gasification Combined Cycle (IGCC), IGCC Power Plants, IGCC Power Plant Cycle Efficiency, Flue Gas De-Sulfurization and Coal Beneficiation, Cold and Hot Gas Clean-Up	10	Understanding of advanced and clean coal technologies
03	**CO_2 from Coal Combustion** Mechanism of CO_2 emission formation during combustion in power plants (steam turbine, gas turbine and internal combustion engines), CO_2 emission reduction by use of alternative fuels and energy efficiency improvement in thermal energy system, Measurement and analysis of CO_2 emission in heat engines/ power plants / thermal energy system	07	Understanding of environmental impacts of conventional coal combustion and clean coal technologies
04	**CO_2 Capture Technologies** Carbon capture: different methods (physical/chemical/biological) of Carbon capture from	07	Overview of Carbon capture technologies

	power plants, CO_2 capture through precombustion methods, Oxygen-combustion method, Post-combustion methods (physical solvents (absorption), sorbents (adsorption), membranes, cryogenic fractionation), and Chemical-looping combustion, and algae species, CO_2 Transportation, CO_2 Storage, Legal Issues, Environmental Health & Safety		
05	**Fuel Cell, Thermoelectric Generator, MHD generator** Fuel Cells; Types of Fuel cells; Fuel Cell Power Plant concepts, Thermoelectric generator, MHD generator, Integration with coal	08	Advanced hybrid energy systems with potential of coal use
Total		**39**	

Course Outcome	Understanding of the prospect of coal as energy resources, environmental impacts of conventional coal combustion, the advanced and clean coal technologies and their Carbon mitigation potential and gaining overview of Carbon capture technologies

Learning Resources	**Text Books:** 1. Bruce G. Miller, Clean Coal Engineering Technology, 2010, Elsevier. 2. P. Jayarama Reddy, Clean Coal Technologies for Power Generation, 2013, Rutledge, Taylor Francis Group. 3. Steve Rackley, Carbon Capture and Storage, Elsevier Publisher, 2010. 4. Mehmet Kanoglu, Yunus A. Cengel, John M. Cimbala, Fundamentals and Applications of Renewable Energy, 2020, McGraw Hill.

Course Code	ME5225N	Course Name	Carbon Capture and Storage	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		Mechanical Engineering		Data Book / Codes/Standards	*Nil*

Course Objective	1. Understanding of carbon cycle, carbon emission, global warming and climate change; 2. Understanding of carbon emission due to fossil fuel combustion and methods of reducing emission from combustion 3. Understanding of different carbon capture technologies and their applications 4. Understanding of Carbon sequestration. transport and storage

Module	Syllabus	Duration (class-hour)	Module Outcome
01	**Introduction** Introduction to Climate Change and the Need to Manage Carbon, The Carbon Problem, Global status of CO_2 emission trends, carbon and CO_2 cycle, Scenario of CO_2 concentration in atmosphere, various impacts of global warming, prediction of future climate changes, global climate models, Policy and Regulatory interventions in abatement of carbon foot print, Kyoto and Montreal protocols and Kigali agreement, Intergovernmental panel on climate change (IPCC), Climate change	08	Understanding of carbon cycle, carbon emission, global warming and climate change
02	**CO_2 from Fossil Fuel Combustion** Mechanism of CO_2 emission formation during combustion in power plants (steam turbine, gas turbine and internal combustion engines), CO_2 emission reduction by use of alternative fuels and energy efficiency improvement in thermal energy system, Measurement and analysis of CO_2 emission in heat engines/ power plants / thermal energy system	07	Understanding of carbon emission due to fossil fuel combustion and methods of reducing emission from combustion
03	**CO_2 Capture Technologies** Carbon capture: different methods (physical/chemical/biological) of Carbon capture from power plants, CO_2 capture through pre-combustion methods, Oxygen-combustion method, Post-combustion methods (physical solvents (absorption), sorbents (adsorption), membranes, cryogenic fractionation), and Chemical-looping combustion, and algae species	09	Understanding of different carbon capture technologies and their applications
04	**Direct Air Capture Technologies** Negative Emissions – A critique and a response, Why direct air capture?, Closing the Carbon Cycle with Air Capture, Negative Emissions the IPCC discussion, Why Air Capture	07	Understanding of different carbon capture

	for Closing the Carbon Cycle, Direct Air Capture, Moisture Swing Technology, Other Air Capture Alternatives, The role of mass production, scaling in numbers vs. size, Mass Production for direct air capture technologies		technologies and their applications
05	**CO_2 Transportation and Sequestration** Carbon Capture and Utilization, Transporting CO_2 (from capture to storage or use), Methane and other greenhouse gases, Carbon storage under empty oil well, Ocean storage, etc. Carbon sequestration: mineral carbonation, Photosynthesis of plants, Fuel production, refrigerant, Dry ice, Fertilizer	08	Understanding of Carbon sequestration. transport and storage
Total		**39**	

Course Outcome	Understanding of carbon cycle, carbon emission, global warming and climate change; In depth knowledge of carbon emission mechanisms due to fossil fuel combustion; methods of improving combustion performance and reducing emission from combustion; knowledge about different carbon capture technologies, Carbon sequestration. transport and storage

Learning Resources	**Text Books:** 1. Steve Rackley, Carbon Capture and Storage, Elsevier Publisher, 2010. 2. Rao.Y, Surampalli, Tian.C.Zhang, et al, Carbon Capture and Storage: Physical, Chemical and Biological methods, American Society of Civil Engineer (ASCE), 2015. 3. Ibrahim Dincer, CalinZamfirescu, Sustainable Energy Systems and Applications, Springer, 2011. 4. Carbon dioxide utilization: Closing the Carbon Cycle, Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Elsevier, 2015 **Reference Books:** 1. Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry, Goel M, Sudhakar M, Shahi RV, TERI, Energy and Resources Institute, 2015. 2. Carbon Capture and Storage, CO2 Management Technologies, Amitava Bandyopadhyay, CRC Press, 2014. 3. IPCC (Intergovernmental Panel on Climate Change) 1990. Climate Change: The IPCC Assessment. Cambridge University Press, Cambridge

Course Code	ME5226N	Course Name	Internal Combustion Engines and Electric Vehicles	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	To impart knowledge on Internal Combustion Engine, Electric Vehicles and their various components.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Components of Battery ignition system, working principle and operation, limitations of conventional breaker operated ignition system and Modern ignition system	03	To understand the basics of ignition system and its components.
2.	Limitation of Simple Carburetor, Solex, Zenith and SU Carburetor. MPFI Engines and its different Sub-systems	04	To study the injection system for SI engines.
3.	Combustion chamber design in CI engines, Concept of Swirl and Squish, Difference between swirl and turbulence, M type combustion chamber, open and turbulent combustion chambers	03	Develop an understanding of different types of CI engine combustion chambers.
4.	Combustion chamber design principle for SI engines, Types of SI engine combustion chambers and their working.	03	Develop an understanding of different types of CI engine combustion chambers.
5.	Alternate fuels for Internal Combustion Engines and the Engine modifications required to operate the existing engines with the alternate fuels.	02	To impart knowledge regarding the future fuels for the IC Engines.
6.	Supercharging and Turbo-charging of Internal Combustion Engines	02	To understand the methods to increase the power output of engines.
7.	Lubricating Oils for IC Engine, Properties of lubricating oil, SAE and API model of classification of lubricating oils, Multi-Grade oils	03	To develop knowledge regarding the types of lubricating oils used in IC engines.
8.	Basic difference between a reciprocating IC engine and Gas turbines, Air Breathing Jet Propulsion system and basics of Rocket Propulsion	04	To understand the working of Jet propulsion system and the rockets.
9.	Introduction and Overview of the Electric Vehicle (EV)	01	To impart basic knowledge of electric vehicles.
10.	Types of Electric Vehicles with their merits	01	To study the types of electric vehicles.
11.	Vehicle Subsystems, Comparison of ICE and EV	03	To study the various components and sub-systems of electric vehicles.
12.	Drive cycle, power requirements	03	To gain knowledge of different

			drive cycle associated with electric vehicles and power requirements.
13.	Introduction to EV battery, battery parameters, BMS, Lithium ion battery, SoS and SoH estimation, Battery pack development and design	04	To understand the battery and related parameters related to the electric vehicles.
14.	EV motors and controllers, EV Chargers	03	To impart basic knowledge of electric vehicle motors, controllers and electric vehicle chargers.
	Total	**39**	

Course Outcome	Students will have specific knowledge on the Internal Combustion Engines and Electric Vehicles as well as their various components.

Learning Resources	**Text book** 1. Internal Combustion Engines Colin R. Ferguson and Allan T. Kirkpatrick, Wiley publishers, 2000. 2. Internal Combustion Engines-Paul W Gill and James H Smith Jr- Oxford and IBH Publishing Co. Fourth Edition, printing 1950. *3.* Engineering fundamentals of the internal combustion engine*, Willard W. Pulkrabek, Pearson Prentice Hall, (2004).* 4. Internal Combustion Engines -V. Ganesan- Tata McGraw-Hill Education Private Limited - Fourth edition, printing 2013. 5. Internal Combustion Engines by M.L. Mathur and R.P.Sharma-Dhanpat Rai Publications-printing 2016. 6. A course in Internal Combustion Engines by V.M. Domkundwar and A.V. Domkundwar-Dhanpat Rai and Co.-printing 2013. 7. Gas Turbines - V. Ganesan- Tata McGraw-Hill Education Private Limited –Third edition, printing 2010. 8. H.N.Gupta, Fundamentals of Internal Combustion Engines, PHI, New Delhi, 2006. 9. Electric Vehicles Theory and Design, Yiqing Yuan, SAE International 10. Electric Vehicle Technology Explained, James Larminie, John Lowry, 2nd Edition, Wiley-Blackwell **Reference books** 1. Internal Combustion Engine Fundamentals – John B. Heywood- McGraw Hill, Inc.-2011. 2. Introduction to Internal Combustion Engines - Richard Stone-Palgrave Macmillan -Fourth Edition, printing 2012.

Course Code	ME-----	Course Name	Carbon Footprint and Carbon Credit	Course Category	VAC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		Mechanical Engineering		Data Book / Codes/Standards	*Nil*

Course Objective	1. Understanding of the nexus between Carbon emission and Climate Change and the concept of sustainability 2. Understanding of Carbon Footprint and the methods of its estimation of Carbon Footprint for different sectors, 3. Understanding LCA, carbon accounting and measurement 4. Understanding of Carbon Markets, Carbon trading and Carbon Credits 5. Carbon mitigation and Net-zero strategies, carbon auditing and certification

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Basics of Carbon cycle, Anthropogenic emissions and their impacts on climate; Greenhouse effect, global warming, prediction of future climate changes, Historical context: Kyoto Protocol, Intergovernmental panel on climate change (IPCC), Paris Agreement, Concepts of sustainability and the SDGs	04	Understanding of carbon cycle, carbon emission, global warming and climate change; Historical perspective
02	Understanding Carbon Footprint Definition and significance Direct vs Indirect emissions , Tools and methodologies for calculating carbon footprints (GHG Protocol, ISO 14064); Life Cycle Assessment (LCA) basics; Carbon footprint for different sectors: energy, transport (land, air and sea), agriculture, manufacturing, commercial and service sectors, ICT	06	Understanding of carbon footprint, the methods of its estimation and LCA
03	Carbon Accounting and Measurement Emission factors; Quantitative methods and data sources, National and organizational carbon accounting, Challenges and uncertainties in measurement Calculation tools and Software: SimaPro, OpenLCA, CoolClimate, etc	06	Understanding of carbon accounting and measurement
04	Carbon Markets and Carbon Credits Carbon offsets,Cap-and-trade vs baseline-and-credit systems, Compliance and Voluntary markets, Carbon pricing mechanisms (taxes, subsidies, incentives)	06	Understanding of carbon markets and trading
05	Policy and Regulatory Frameworks International frameworks: UNFCCC, IPCC guidelines; National policies on carbon accounting and trading; Corporate carbon disclosure and	04	Understanding of policy and regulatory frameworks related to carbon trading

	reporting		
06	Carbon mitigation and Net-zero strategies for different sectors, Carbon-neutral products and services; Role of technology: renewables, CCS (Carbon Capture and Storage), Direct capture and Carbon negative systems	06	Understanding of Carbon mitigation and Net-zero strategies
07	Carbon auditing procedures; Verification and validation bodies; Certification standards and processes; Ethical, Social and Economic Dimensions; Environmental justice and carbon inequality	04	Understanding of carbon auditing and verification; social and economic dimensions;
Total		**36**	

Course Outcome	1. Understanding of carbon cycle, Carbon emission, Climate Change, Carbon Footprint and the methods of its estimation of Carbon Footprint, Carbon mitigation and Net-zero strategies; Knowledge about Carbon Markets, Carbon trading, Carbon Credits, carbon auditing and certification

Learning Resources	**Text Books:** 1. Climate Change: The IPCC Assessment. Cambridge University Press, Cambridge. 2. Carbon dioxide utilization: Closing the Carbon Cycle, Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Elsevier, 2015 3. Understanding Carbon Credits: A Guide for Beginners, Gurmit Singh 4. Steve Rackley, Carbon Capture and Storage, Elsevier Publisher, 2010. 5. Ibrahim Dincer, Calin Zamfirescu, Sustainable Energy Systems and Applications, Springer, 2011 **Reference Books:** 1. IPCC (Intergovernmental Panel on Climate Change) Reports. 1990 2. ISO 14064 3. Carbon Management, Climatic Change, Environmental Science & Policy (Journals issues) 4. Carbon Footprints: Case Studies from the Building, Household, and Agricultural Sectors (Environmental Footprints and Eco-design of Products and Processes), Springer 5. Carbon Capture and Storage, CO2 Management Technologies, AmitavaBandyopadhyay, CRC Press, 2014

Course Curriculum
for
Machine Design

Course Code	ME5106N	Course Name	Advanced Solid Mechanics	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	1) Mathematics I (MA-1101) 2) Mathematics II (MA-1201) 3) Strength of Materials (AM-2101) or, Equivalent Courses	Co-requisite Courses	1) Mini Project on Advanced Solid Mechanics (ME-5178)	Progressive Courses	1)Applied Elasticity and Plasticity (ME-5131)
Course Offering Department	*Mechanical Engineering*		**Data Book / Codes/Standards**		Nil

Course Objective	1) To make students understand the engineering properties of materials and constitutive relationships 2) To make students establish governing equations of engineering components with more complex geometries, and, subjected to more complex static loadings 3) To make students able to identify appropriate boundary conditions and solve the governing equations

Module	Syllabus	Duration (class-hour)	Module Outcome
Fundamentals of Stress and Strain	Stress tensor, Traction vector, Cauchy's Stress Equation, Equilibrium equation in Cartesian coordinates, Equality of Cross Shears, Strain displacement relation, Compatibility condition, Stress-Strain relation, Generalized Hook's Law,	06	After successful completion of the module, the students will be able to UNDERSTAND state of stress and strain, equilibrium equation, strain-displacement relationship, strain compatibility conditions and stress-strain constitutive relationships for linear elastic solids. **(CO1)**
Axisymmetric deformation in thick cylinders and discs	Concept of plane stress, plane strain, derivation of Lame's equation for thick-walled cylinders subject to internal and external pressure, stresses produced by shrink fit, stresses in rotating discs and cylinders	05	After successful completion of the module, the students will be able to ANALYSE stresses and deformations for axisymmetric problems of linear elastic solids with mechanical loadings. **(CO2)**
Thermal stresses in disks and cylinders	Derivation of thermo-elastic stress-strain relations, stresses and deformation in an element of thin circular disk under symmetrical temperature distribution about the centre, stresses and deformation in a long hollow cylinder, solution of problems under known temperature distribution	04	After successful completion of the module, the students will be able to ANALYSE stresses and deformations for axisymmetric problems of linear elastic solids with thermos-mechanical loadings. **(CO2)**
Beam-columns	Derivation of fundamental equation for beam-columns, determination of deflection, slope and moment of beam-columns under various loading conditions	03	After successful completion of the module, the students will be able to ANALYSE stresses and deformations for beam-columns. **(CO3)**
Beams on elastic	Definition of modulus of elastic foundation, deflection equation of beams,	03	After successful completion of the module, the students will be able to

foundation	determination of deflection, shear force and moment of infinitely long beam under various loading conditions		ANALYSE stresses and deformations for beams on elastic foundation. **(CO3)**
Bending of straight beams with asymmetrical section	Difference between symmetrical and unsymmetrical bending, derivation of stresses for straight beams with unsymmetrical sections, shear centre, shear stresses in thin-walled open sections	05	After successful completion of the module, the students will be able to ANALYSE stresses and deformations for straight beams with asymmetrical section. **(CO3)**
Torsion of non-circular prismatic bars - solid section	Concept of warping function, stress function, derivation of general governing equation of torsion, derivation of expressions for torque and shear stresses for elliptic, triangular and rectangular cross-sections	05	After successful completion of the module, the students will be able to ANALYSE stresses and deformations for torsional load on solid non-circular prismatic bars. **(CO4)**
Bending of plates and shells	Concept of flexible rigidity of plates, derivation of basic equations of bending due to moments about the edges, generalised slope function and deflection function, determination of slope function, deflection, moment and maximum bending stress under various loading conditions of plates	06	After successful completion of the module, the students will be able to ANALYSE stresses and deformations from bending of plates and shells. **(CO5)**
Two dimensional problems in polar coordinates	Stress distribution due to concentrated force at a point of flat boundary, effect of circular holes on stress distribution in plates	03	After successful completion of the module, the students will be able to EVALUATE 2D problems in polar coordinates. **(CO6)**
Total:		**40**	

Course Outcome	After successful completion of the course, the students will be able to: 1) UNDERSTAND state of stress and strain, equilibrium equation, strain-displacement relationship, strain compatibility conditions and stress-strain constitutive relationships for linear elastic solids 2) ANALYSE stresses and deformations for axisymmetric problems of linear elastic solids with mechanical and thermos-mechanical loadings. 3) ANALYSE stresses and deformations for straight beams with asymmetrical section, beams on elastic foundation and beam-columns 4) ANALYSE stresses and deformations for torsional load on solid non-circular prismatic bars 5) ANALYSE stresses and deformations from bending of plates and shells 6) EVALUATE 2D problems in polar coordinates

Learning Resources	1) Advanced Mechanics of Solids, L. S. Srinath, McGrawHill 2) Theory of Elasticity, S. P. Timoshenko and J. N. Goodier, McGrawHill 3) Strength of Materials, S. P. Timoshenko, Vols. 1 and 2, CBS Publishers 4) Advanced strength of materials, D. Hartog, McGraw Hill 5) An Introduction to the Mechanics of Solids, S. H. Crandall, N. C. Dahl and T. J. Lardner, McGraw Hill 6) Continuum Mechanics and Theory of Materials, P Haupt, Springer publications

Course Code	ME5107N	Course Name	Linear and Nonlinear Vibration	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	The students need to have knowledge of UG Mechanics	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			**Data Book / Codes/Standards**	*Nil*

Course Objective	Both Linear and Nonlinear Vibration of Mechanical Systems will be taught in this course. Linear Vibration 1. To provide students with basic understanding of Mechanical Vibrations and corresponding physical modelling 2. To make the students learn the procedure of deriving Equations of Motions (EOMs) for discrete or continuous systems 3. To make the students equipped with some mathematical techniques to solve and analyze the EOMs 4. To make the students understand the different phenomenon associated with vibration by solving/analyzing the EOMs 5. To make aware about the practical aspects of vibration and suppression/control of it Nonlinear Vibration 1. To make the students aware of the nonlinear aspect of the vibrating systems and how it differs from the linear ones 2. To make the students equipped with some geometric and analytical techniques to analyze certain aspects of nonlinear systems 3. To make the students learn to apply those techniques for 1D and 2D systems 4. To make the students learn about few phenomenon associated with nonlinear systems

Module	Syllabus	Duration (class-hours)	Module Outcome
Introduction	Degrees of freedom, Lumped parameter modeling of systems, Lagrange equation	03	The students will be able to system modeling and derive the EOMs
single degree-of-freedom model	Free vibration, Forced vibration, Damped vibration, Resonance, Vibration isolation	06	The students will be able to develop (and apply) concepts regarding free (natural frequency, viscous and friction damping, logarithmic decay, damped frequency etc.) and forced (resonance, transmissibility etc.) vibration of SDOF systems.
Two/multi degrees of freedom model	Mass and stiffness and damping matrix, Eigen value problem in vibration, Modes of vibration, Modal decomposition method of forced vibration	05	The students will be able to develop (and apply) comprehensive understanding of key mathematical techniques related to free and forced vibration of MDOF systems.
Vibration of elastic bars and shafts	Equation of motion, Natural frequency and mode shapes under different boundary conditions	06	The students will gain comprehensive understanding of vibration a few continuous systems.

Understanding Nonlinearity	Properties of Linear systems, Sources of Nonlinearity, Linear and Nonlinear Springs, Examples of Different Nonlinear Oscillators, Non-dimensionalization.	04	The students will be able to 1. differentiate between linear and nonlinear systems. 2. do non-dimesinlization 3. give examples of nonlinear systems
Geometric Understandings	Issues with Closed Form Solution, State/Phase Space Fixed Points, Linear Stability Analysis (first-order system), Second Order Conservative Systems: Duffing and Other Oscillators	05	The students will have comprehensive idea about closed form solution, state space, autonomous and non-autonomous systems The students will be able to 1. find out fixed points 2. do linear stability 3. characterize the fixed points of 2nd order conservative systems and draw phase portrait
General Second-Order Systems	Linearization, Linear Stability Analysis of Fixed Points.	04	The students will be able to 1. linearize general 2nd order nonlinear system 2. characterize the fixed point sand draw corresponding local phase portrait
Limit Cycle	Definition, van der Pol Oscillator, Existence and Non-existence of Limit Cycle, Liénard equation, Relaxation Oscillator	04	The students will have comprehensive understanding of limit cycle and associated topics
Bifurcations	Static Bifurcations: Turning Point, Transcritical, Pitchfork. Dynamic Bifurcation: Hopf.	03	The students will have comprehensive understanding of static and dynamic bifurcations
Nonlinear Stability Analysis	Stability: Lyapunov, Asymptotic, Exponential. Lyapunov Stability Criteria.	02	The students will have brief understanding of Lyapunov stability and corresponding stability criteria
Total		**42**	

Course Outcome	**Linear Vibration** 1. The students must be able to tell the difference between Free and Forced Vibrations; discrete and continuous systems 2. The students must be able to model and derive the EOMs 3. The students must be able to analyze EOMs 4. The students must have reasonable idea (both practical and mathematical) about damping, natural frequency, resonance, vibration isolation, mass/stiffness matrix, mode shapes, modal analysis **Nonlinear Vibration** 1. The students must be able to tell the difference between linear and nonlinear systems 2. The students must be aware of the source where from nonlinearity may creep into the systems 3. The students must have reasonable idea about state-space, fixed point, linear stability analysis (LSA), Limit Cycle, Bifurcation and Stability of a solution 4. The students must be able to apply LSA for different systems

	5. The students will be able to have comprehensive understanding of limit cycle, bifurcation and nonlinear stability

Learning Resources	**Text Book: (For First Four Modules)** 1. Mechanical Vibration, S. S. Rao, 5th ed., Prentice Hall **Reference Book: (For First Four Modules)** 1. Principles of Vibration, B. H. Tongue, Oxford University Press (Indian edition). **Text Book: (For Last Six Modules)** 1. S. H. Strogatz, Nonlinear Dynamics and Chaos, Addison-Wesley, Reading, MA, 1994. **Reference Book: (For Last Six Modules)** 1. D. W. Jordan and P. Smith, Nonlinear Ordinary Differential Equations, Oxford University Press, New York, 1999.

Course Code	ME5108N	Course Name	Geometric Modelling for CAD	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	In today's perspective CAD has widespread applications not only for designing a product or an assembly but also for different analysis with it. This course gives detail knowledge about the fundamental structure and the mathematical basis of any CAD software. The mathematical basis contains the modelling features of a real life object and its graphic representation.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Basics of CAD and terminology, Raster and vector image, Basics of transformation, Data format : IGES, DXF etc.	04	To get the students conversant with the terminology, types and data exchange formats for CAD platforms
2	Non-parametric and parametric representation of curves, Analytic and synthetic curves.	03	Different mathematical formats for representing curves
3	Design of synthetic curves: Cubic spline, Bezier and B-Spline curve.	10	To know about the different forms of parametric representation of real-life curves
4	Basics of surface design: tangent, twist, normal vectors, geodesic etc. Gaussian curvature, criterion for developable surface.	03	Parametric representation of real-life surfaces; their tangent, normal and twist vector
5	Design of surfaces: Ruled, Linear and Bicubic Coon's surface, Bezier surface. Operations on surfaces: joining, reparametrization and truncation.	10	Detail knowledge of different forms of surfaces to suit the requirements of different industries
6	Solid modeling: terminology, primitives, Boolean operations, Basics of Constructive Solid Geometry and Boundary Representation.	08	To make the students aware of different solid modelling techniques and their detail operations.
7	Programming with AutoLISP , SolidWorks modeling, CATIA	04	To make the students confident on working with different CAD systems to develop complicated model and to write program to create a CAD model automatically
Total		**42**	

Course Outcome	Knowledge of a specific CAD software is not the aim of this course. Students will gain knowledge about the fundamental basis on which such CAD software are built. With this generic knowledge on CAD software they can work on any CAD system for designing a complicated product. Knowledge of automated CAD programming c (i.e., repetitive drawings on CAD based on parameters) can save lot of time for industry.

Learning Resources	**Text Book:** 1. Mathematical Elements for Computer Graphics - D. F. Rogers & J. A. Adams; Tata McGraw Hill, New Delhi **Reference Books:** 1. Mathematic for Computer Graphics Applications - M.E. Mortension; Industrial Press Inc. New York. 2. Modeling of Curves and surfaces in CAD/CAM - M. Hosaka; Springer-Verlag. 3. CAD/CAM : Theory and Practice:Ibrahim Zeid, R Sivasubramanian ; McGraw Hill Pub. 4. AutoLISP Manual; AUTODESK 5. MATLAB: An introduction with application - Amos Gilat; Wiley India

Course Code	ME5132N	Course Name	Engineering Tribology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Machine Design*	Co-requisite Courses	*Mathematics*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students with a comprehensive understanding of the tribology aspects during contact between two mating surfaces. Theoretical aspects are addressed to understand friction and wear phenomena between two surfaces in contact with and without lubrication. Emphasis is given to different kinds of wear mechanisms happened in various applications.

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Introduction: A brief history of tribology, and industrial importance.	02	Addressing basics of tribology and its importance in industries.
02	Engineering surfaces - properties and measurement: Surface profilometer, optical microscopy, electron microscopy, and statistical and fractal description of surface roughness.	06	Understanding of engineering surfaces, their configurations and measuring techniques.
03	Contact between surfaces: Geometry of non-conforming surfaces in contact, surface tractions, surface and subsurface stresses, and contact of rough surfaces.	06	Understanding of contact geometries, and surface and subsurface stresses.
04	Adhesion at solid-solid contact: Adhesion models, factors influencing adhesion, and adhesion at the contact between rough surfaces.	04	Presenting configurations of adhesion contact and concerned models.
05	Friction theories: Genesis of solid friction, simple adhesion theory, modified adhesion theory, deformation theory, measurement tools, and friction of metals and non-metallic materials.	06	Presenting simple and modified adhesion theories, friction of metals and non-metallic materials, and measuring tools.
06	Mechanisms of Wear: Adhesive wear, abrasive wear, erosive wear, cavitational wear, chemical wear, surface fatigue wear, wear of metals, and non-metallic and composite materials.	06	Understanding of different wear mechanisms.
07	Thermal considerations in sliding contact: Measurement of surface temperature in sliding, and theoretical analyses.	04	Presenting thermal aspects at sliding contact, measurement of surface temperature during sliding and concerned theoretical analyses.
08	Tribo-testing tools: Measurement of friction and wear.	02	Presenting configurations of different tribo-testing tools.
09	Lubrication regimes: Thick-film and thin-film lubrication.	06	Understanding of lubrication regimes including thick-film and thin-film lubrication.
	Total	**42**	

Course Outcome	At the end of the course, students should be able to 1. Understand the aspects of tribology and its importance in industries. 2. Understand contact mechanisms at surface and subsurface levels. 3. Measure surface characteristics like roughness, curvature *etc*. through profilometer. 4. Apply the concepts to understand adhesion phenomenon at the contact between two surfaces. 5. Understand and measure friction and wear values during the sliding contact between two surfaces at the ambient and elevated temperatures. 6. Conceptualize lubrication.

Learning Resources	**Text Book** 1. Engineering Tribology - J. A. Williams, Oxford University Press, Reprint 1996 **Reference Books** 1. Fundamentals of Fluid Film Lubrication - B. J. Hamrock (McGraw Hill International) 2. Engineering Tribology – Prasanta Sahoo, Prentice-Hall of India Pvt. Ltd., 2005 3. Friction and Lubrication of Solids – Part I & Part II , F. P. Bowden and D. Tabor, Oxford University 4. Contact Mechanics – K. L. Johnson, Cambridge University Press 5. Tribophysics – Nam P. Suh, Prentice-Hall INC Press.

Course Code	ME5133N	Course Name	Applied Elasticity and Plasticity	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	1. Mathematics I (MA-1101) 2. Mathematics II (MA-1201) 3. Advanced Solid Mechanics (ME-5106) or, Equivalent Courses	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards	Nil		

Course Objective	1) To make the students revise the foundational understanding of theory of elasticity 2) To make the students acquainted with the stress-based and energy-based approaches for solving advanced elasticity problems 3) To provide the students foundational understanding of behaviour of metals after permanent deformation 4) To prepare the students to solve machine design and form manufacturing related problems involving plastic deformations 5) To introduce plastic instability and damage in engineering components and structures, to the students

Module	Syllabus	Duration (class-hour)	Module Outcome
Review of Stress Analysis	a) Stress tensor and Traction vector. Coordinate rotation & transformation of stress tensor, Principal stress and Principal coordinate, Maximum shear stress, Shearstress in octahedral plane b) Strain displacement relation, Compatibility condition. c) Stress Strain relation, Generalized Hook's Law d) d) Equilibrium equation in Cartesian and curvilinear coordinates	3+1+1+2=07	After successful completion of the module, the students will be able to REMEMBER the foundational theory of elasticity for the elastic materials. **(CO1)**
Stress Function	Concept of stress function, Solution of 2D elasticity problems using stress function in i) Cartesian coordinate ii) polar coordinate	04	After successful completion of the module, the students will be able to ANALYSE 2D elasticity problems using the stress functions. **(CO2)**
Strain Energy	Concept of strain energy, Principle of virtual work, Solution of2D elasticity problem using principle of virtual work	03	After successful completion of the module, the students will be able to ANALYSE 2D elasticity problems using the concept of the strain energy. **(CO2)**
Plastic Yielding & Flow	a) Yield function and its physical interpretation, Yield surface and Yield locus, Tresca and Von mises Yieldfunction. Geometric interpretation of Tresca and von-Mises Yield surface and Yield locus, von-Misesequivalent stress and equivalent plastic strain, Plasticwork	5+5=10	After successful completion of the module, the students will be able to UNDERSTAND fundamentals of theory of plasticity for metals –Yielding, Plastic Flow. **(CO3)**

	b) Flow rule: - Prandtl-Reus equation, Levy-Misesequation, Normality condition & associated flow rule.Plastic potential & Hill's principle of maximum dissipation. Stress Strain relation of elastic-plastic material		
Hardening Rule	Elastic-perfectly plastic material & elastic-plastic material, Concept of strain hardening and work hardening, Isotropic hardening and Kinema hardening rules, Mixed hardening, Determination of flow curve	04	After successful completion of the module, the students will be able to UNDERSTAND fundamentals of theory of plasticity for metals - Hardening. **(CO3)**
Analytical solution of plasticity problem without hardening(elastic-perfectly plastic material)	i)Bending of prismatic beam ii)Torsion of prismatic bar iii)Thick cylinder with internal pressure	05	After successful completion of the module, the students will be able to ANALYSE bending, torsion and axisymmetric problems with permanent deformations. **(CO4)**
Plane strain problem	i) Slip line theory and its application ii) Solution of 2D metal forming problem using slip line theory	04	After successful completion of the module, the students will be able to ANALYSE form manufacturing problems. **(CO5)**
Plastic Instability	i) Concept of plastic instability, Drucker's postulate ii)Instability of tensile bar iii) Determination of instability pressure of thin cylinder and sphere	03	After successful completion of the module, the students will be able to UNDERSTAND the concept of plastic instability. **(CO6)**
Total:		**40**	

Course Outcome	After successful completion of the course, the students will be able to: 1. REMEMBER the foundational theory of elasticity for the elastic materials 2. ANALYSE 2D elasticity problems using the stress functions and the concept of the strain energy 3. UNDERSTAND fundamentals of theory of plasticity for metals - Yielding, Plastic Flow and Hardening 4. ANALYSE bending, torsion and axisymmetric problems with permanent deformations 5. ANALYSE form manufacturing problems 6. UNDERSTAND the concept of plastic instability

Learning Resources	1. Advanced Mechanics of Solids, L. S. Srinath, McGrawHill 2. Theory of Elasticity, S. P. Timoshenko and J. N. Goodier, McGrawHill 3. Strength of Materials, S. P. Timoshenko, Vols. 1 and 2, CBS Publishers 4. Theory of Plasticity, J. Chakraborty, Butterworth-Heinemann Ltd. 5. Plasticity for Engineers,W. Johnson and P. B. Mellor, Van Nostrand Reinhold Inc. 6. Foundations of the Theory of Plasticity, L. M. Kachanov, North-Holland Publishing Company 7. Introduction to Engineering Plasticity, by G.K. Lal and N. Venkata Reddy, Alpha Science International Ltd.

Course Code	ME5134N	Course Name	Advanced Mechanics of Machines	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	*Nil*

Course Objective	The objectives of the course are as follows: 1. To revise the foundational understanding of Mechanisms, Degree of Freedom, Velocity and Acceleration analysis 2. To make students learn about different advanced topics related to plane and spatial motion 3. To make students learn how to perform kinematic analysis of mechanisms and manipulators 4. To make students learn about synthesis of mechanisms (both Graphical and Analytical)

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction	Applications of mechanisms, nomenclature, kinematic pairs, kinematic chains, kinematic diagrams, Degree of freedom-Gruebler and Kutzbach criterion	05	Understanding of fundamentals of mechanisms
Number Synthesis	Calculation of number of joints and links for given DOF	05	Learning basic kinematic design calculations
Grashof's Criterion and its extensions	Rotatibility criterion for different kinematic chains	04	Learning kinematic response of different simple mechanisms
Advanced Kinematics of Plane Motion	Euler equation- 2D and 3D Coriolis acceleration	05	Review of kinematics of rigid bodies
Kinematic analysis of planar mechanisms	Analytical methods of displacement, velocity and acceleration analysis of planar mechanisms Singularity configurations (Dead center and change points)	07	Learning to perform kinematic analysis of mechanisms by hand or computer program (for complex systems)
Kinematic analysis of spatial mechanisms	Denavit-Hartenberg parameters, Homogenous Transformations. Rigid Transformations. Forward and Inverse kinematics of Robotic manipulators	07	Learning to perform kinematic analysis of 3D mechanisms and robotic manipulators
Screw Theory	Modern methods of kinematic analysis	04	Learning modern methods of kinematic anlysis
Introduction to Synthesis-Graphical and analytical methods	Three and four position synthesis Frudenstein's equation Function generator Coupler curve synthesis	05	Learning how to design mechanisms for given objectives
Total		**42**	

Course Outcome	After the completion of the course, the students will be able to 1. Find DOF, do velocity and acceleration analysis of different mechanisms 2. Do different advanced kinematic analysis (using the different techniques taught) related to plane/spatial motion of mechanisms 3. Design and synthesize (using the different techniques taught) different mechanisms based on the provided objectives

Learning Resources	**Text books**: 1. *Kinematics and Dynamics of plane mechanisms*/ Jeremy Hirschhorn/McGraw-Hill,1962. 2. *Theory of Machines and Mechanisms*/ J.E Shigley and J.J. Uicker Jr./ McGraw-Hill, 1995 3. *Theory of Mechanisms and Machines*/ Amitabh Ghosh and Ashok Kumar Mallik/ E.W.P. Publishers. 4. *Kinematics and Linkage Design*/ Allen S. Hall Jr./ PHI,1964. 5. *Kinematics and Dynamics of Machinery*/Charles E Wilson/Pearson/3rd Edition.

Course Code	ME5135N	Course Name	Design Optimization	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The objectives of the course are as follows: 1. To provide students with the understanding of the optimization problem, the importance of it and how to formulate and write a formal optimization problem statement 2. To make the students learn the different procedures (methods) of solving both constrained (univariate) and unconstrained (univariate) optimization problems 3. To make the students learn the different procedures (methods) of solving both constrained (multivariate) and unconstrained (multivariate) optimization problems 4. To make the students learn the methods of solving Linear and Quadratic programming 5. In advanced topics, the students will learn about Genetic Algorithm mainly

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction	Introduction and overview of optimization problems including the notion of convergence and convexity	03	Students will get acquainted with the essential notions of optimization
Univariate Unconstrained Optimization	Basics of univariate unconstrained minimization	03	Students will learn to solve univariate unconstrained minimization problems
Multivariate Optimization	Fundamentals of multivariate optimization including equation solving and least squares problem	04	Students will learn to solve multivariate unconstrained optimization problems
	Discussion of professional (applied) methods for multivariate optimization	04	
Constrained Optimization	Basics of constrained optimization	06	Students will learn to solve multivariate constrained optimization problems by analytical methods
	Linear programming problems	03	
	Quadratic programming problem	05	
Different Family of Methods	Different family of methods for solving a constrained optimization problem	06	Students will learn to solve multivariate constrained optimization problems by different family of methods
Advanced Topics	Advanced topics	06	Students will learn to solve multivariate constrained optimization problems by numerical methods
Total		**42**	

Course Outcome	After completion of the course, the students should be able to 1. Learn to think about optimization problems 2. Formulate and write optimization problem statements 3. Identify different types of constraints and feasibility of the solution 4. Learn and apply different optimization methods (that have been taught) 5. Code the methods

Learning Resources	**Text books**: 1. Optimization for Engineering Design. K Deb. 2. Optimization concepts and applications in engineering, A. D. Belegundu and T. R. Chandrupatla. 3. Linear and Nonlinear programming. S. Nash and A. sofer.

Course Code	ME5136N	Course Name	Biomechanics	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Engineering Mechanics; Strength of Materials	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards			Nil

Course Objectives	The goal of the course is to introduce the fundamental concepts of engineering principles to solve problems in the domain of medicine and biology. It aims to equip students to apply the knowledge of engineering mechanics and engineering design to the human body, particularly in orthopaedics. The major focus is to make students understand the mechanics of the musculoskeletal system, anatomy and biomechanics of bones and joints, biomechanics of orthopaedic implants, biomechanics of human movement and predict the effects of altered loading on tissues to address biomechanical problems.

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction	Basic terminologies, applications, concepts and function of the human musculoskeletal system, review of basic Mechanical Engineering concepts	04	Students should be able to understand the basic terminology, identify application areas and consolidate their understanding of the basic mechanical engineering concepts behind
Musculoskeletal system	Composition, structure, function, and biomechanical behaviour of bone, cartilage, muscle, ligament and tendon.	06	Students should be able to understand the structure and functions of the biological tissues and musculoskeletal system, and the mechanical properties of biological tissues
Biomechanics of human joints	Structure, range of motions and musculoskeletal model of forces for human joints (hip, knee, ankle, shoulder, elbow and spine).	08	Students should be able to understand the basic biomechanics of natural joints in the human body and apply the concepts to solve problems related to the force analysis of the joints
Design and analysis of orthopedic implants	Design consideration of artificial joints (hip, knee, ankle, shoulder, elbow and spine), failure mechanisms, finite element modelling and mechanical testing.	10	Students should be able to understand and analysethe major steps of the orthopaedic implant design process. Also, evaluate the relative importance of various design parameters.
Bone remodeling and bone ingrowth	Bone remodeling, fracture healing in bone, mechanobiology-based bone in growth and tribology of synovial joints.	06	Students should be able to understand the biological process of bone remodeling and bone in growth in depth.
Human motion and gait analysis	Joint kinematics, gait cycle, measurement techniques in gait analysis, estimation of musculoskeletal forces, and example applications.	08	Students should be able to understand the basic principles behind the estimation of musculoskeletal forces.

	Total	**42**	

Course Outcome	At the end of the course, students should be able to 1. Understand the basic concepts of engineering principles used in solving problems in orthopaedics 2. Understand the basic anatomy and biomechanics of bones and joints, the mechanical properties of biological tissues and the biomechanics of human movements. 3. Apply the concepts learned to solve problems in the field of orthopaedic biomechanics 4. Analyze the design process of orthopaedic implants 5. Evaluate the relative importance of various design considerations of orthopaedic implants 6. Develop virtual/physical models of orthopaedic reconstructions by assembling various information

Learning Resources	**Text Books** 1. Basic Biomechanics of the Musculoskeletal System, 4th Edition, M Nordin and VH Frankel, Lippincott Williams and Wilkins, 2012. 2. Fundamentals of Biomechanics: Equilibrium, Motion, and Deformation. 4th Edition, N Ozkaya, D Leger, D Goldsheyder, M Nordin, Springer, 2017. 3. Biomechanics of Joints and Implants: Concepts to Applications, 1st Edition, S Gupta,CebyMS, B Pal, S Chanda, K Mukherjee, Springer Nature, 2025 **Reference Books** 1. Biomechanics - Mechanical Properties of Living Tissue, YC Fung, Springer Verlag, 1993. 2. Fundamentals of Biomechanics, 2nd Edition, D Knudson, Springer, 2017.

Course Code	ME5162N	Course Name	Industrial Robotics	Course Category	OE	L	T	P
						3	0	0

Pre-requisite Courses	*Mechanics*	Co-requisite Courses	*Mathematics*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students with a comprehensive understanding of the robotics of various industrial application to improve and integrate with industry 4.0. The specific objectives are to equip students with the concepts of the robot kinematics, drive systems, control, robot vision, sensors and programming for various industrial need.

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction	Definition, Law of Robotics, Anatomy of a Robot, Robot Classification, Geometric Configurations, Robot Specifications	02	Learn basic features and anatomy of robots
Robot Drive System	Introduction to Actuators, Electric Actuators	02	Learn basic function of actuators
Robot Arm Kinematics	Rigid Body Rotation: Rotation Matrix, Axis-angle or Rodrigues' Rotation Formula, Successive Rotations. Forward Kinematics: Homogeneous Transformation, Representation of Joints and Link, Denavit-Hartenberg Parameters. Inverse Kinematics: Solvability and Solution Techniques.	11	Understand the robot forward, inverse kinematics and Robot DH parameters.
Differential Motion and Velocity	Differential Motions of Frames and Robot Joints, Robot Jacobian, Inverse differential Kinematics.	04	Learn the robot frame motion and robot Jacobian
Manipulator Dynamics and Robot Control	Euler-Lagrange Equations: Derivation using virtual work and Application to Robot Manipulators. Linearization of EOMs. Linear Control: Transfer functions, PID Controller, Routh Criteria, Introduction to Controller Design. Modern Control: State Space, Observability and Controllability, Introduction to LQR.	13	Learn in details about the various robot control techniques and robot manipulators
Robotic Vision System	Process of Imaging: Architecture of Vision system, Image Acquisition. Image Digitization and Storage. Image Processing and Analysis: Data reduction, Segmentation, Feature extraction and Object recognition.	05	Get the detailed robot vision systems, image digitization and storage techniques for subsequent applications.
Trajectory Generation	Joint Space Schemes: Polynomial Trajectories.	02	Understand the various joint space scheme
Robot Programming and Languages	Methods of Robot Programming: Lead through Programming Methods, Textual Robot Languages. Elements and Functions of Robot Language, Variable Assembly Language (VAL)	02	Learn and accustomed with various robot programming based on specific use

Industrial Applications	Application of Robots in Material Handling, Machine Loading and Unloading, Welding, Spray Painting, Robotic Assembly, Safety in Robotics.	01	Understand the various robotic application for material handling and other industrial applications in modern days
Total		**42**	

Course Outcome	At the end of the course, students should be able to 1. Understand the robot anatomy and robot kinematic for various applications. 2. Understand robot drive systems, forward and reverse kinematics, various representation of robot joints, links and dynamics, control of various motion. 3. Knowledge on robot vision and sensors used for various industrial and research application. 4. Apply the concepts learned to solve various robotic applications based on industry need. 5. Develop robot programming based on specific application using available robot programming languages 6. Overall and industry specific robotic applications to improve and integrate with industry 4.0.

Learning Resources	**Text Book** 1. M. P. Groover, M. Weiss, R. N. Nagel and N. G. Odrey, Industrial Robotics: Technology, Programming and Applications, Tata McGraw-Hill, New Delhi, 2008. **Reference Books** 1. R. K. Mittal and I. J. Nagrath, Robotics and Control, Tata McGraw-Hill, New Delhi, 2007. 2. K. S. Fu, C. S. G. Lee and R. Gonzalez, Robotics: Control, Sensing, Vision and Intelligence, Tata McGraw-Hill Education, 1987. 3. S. K Saha, Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2014. 4. S. R. Deb and S. Deb, Robotics Technology and Flexible Automation, Tata McGraw-Hill, New Delhi, 2010. 5. K. Ogata: Modern Control Engineering, Prentice Education India, 2015.

Course Code	ME5206N	Course Name	Fatigue, Creep and Fracture Mechanics	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	1. Mathematics I (MA-1101) 2. Mathematics II (MA-1201) 3. Fundamentals of Machine Design (ME-2203) 4. Advanced Solid Mechanics(ME-5106) or, Equivalent Courses	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	*Mechanical Engineering*	**Data Book / Codes/Standards**	ASTM E139 ASTM E399 ASTM E606 ASTM E1820		

Course Objective	1) To make students proficient in using the more practical fatigue damage criteria for metals in machine design. 2) To make students acquainted with the concepts of fracture mechanics in engineering design for different materials under static loading conditions as a realistic alternative of classical strength-based design with large factor of safety.

Module	Syllabus	Duration (class-hour)	Module Outcome
Fracture Mechanics	Theoretical Cohesive strength of Material (An Atomic View), Stress concentration effect of Flaws, Griffith Energy Balance. Energy Release Rate, Instability, R – curve.	05	After successful completion of the module, the students will be able to UNDERSTAND the damage mechanisms of materials under quasi-static loading **(CO1)** and EVALUATE the fracture parameters for linear elastic materials. **(CO2)**
	Crack tip stress field analysis, Stress Intensity Factor, K-dominated field, Crack tip plastic zone (Irwin model/Dugdale model), Plane stress/plane strain fracture Mechanics.	04	
	J Contour Integral, Path independence of J-integral - Example, Crack Tip Opening Displacement (CTOD), J-R curve, Ductile crack growth and Instability, Tearing Modulus	05	
Fatigue of Metals	Concept of Fatigue failure, High cycle fatigue (Stress-based fatigue) - Definition of stress cycles, fatigue life and endurance limit, S-N curve and Wohler Diagram, effect of mean stress and stress ratio on fatigue life, the Soderberg, Goodman and Gerber plots, effect of notch on fatigue life, Basquin equation for stress-based fatigue life calculation, fatigue strength coefficient and fatigue strength exponent.	06	After successful completion of the module, the students will be able to UNDERSTAND the damage mechanisms of materials under quasi-static, time dependent and varying direction (and magnitude) loading **(CO1)** and EVALUATE the life of materials under fatigue loading conditions by considering environment and other factors. **(CO3)**
	Low Cycle Fatigue (Strain-based fatigue) - Hysteresis loop, steady-state loop, cyclic stress - strain curve, Coffin-Massion equation, fatigue ductility coefficient and fatigue ductility exponent, total strain life curve (Morrow's equation), Mean stress correction - (i) Morrow's method (ii) Smith Watson Topper's method	05	

	Paris Law and its modifications, over loading effect, Variable amplitude loading, Determination of FCGR Curve	03	
	Fatigue damage accumulation and life exhaustion, Linear damage rule (Palmgren-Miner Rule), cycle counting methods	02	
Creep of Metals	Definition of creep, creep strength, creep rupture strength, various stages of graphical creep-time variation, various creep-stress-time relations, creep in bending of beam of rectangular and circular cross-sections, creep in torsion of shaft, derivation of principal creep strains under combined state of stresses, creep design of thick-walled cylinders subject to internal pressure, solution of numerical problems on creep design	10	After successful completion of the module, the students will be able to UNDERSTAND the damage mechanisms of materials under quasi-static, time dependent and varying direction (and magnitude) loading **(CO1)** and EVALUATE creep deformation related problems for materials.**(CO4)**
Total :		**40**	

Course Outcome	After successful completion of the course, the students will be able to: 1) UNDERSTAND the damage mechanisms of materials under quasi-static, time dependent and varying direction (and magnitude) loading. 2) EVALUATE the fracture parameters for linear elastic materials, linear elastic materials with small scale yielding and materials with large scale yielding 3) EVALUATE the life of materials under fatigue loading conditions by considering environment and other factors, the fatigue crack growth rate and fatigue damage 4) EVALUATE creep deformation related problems for materials.

Learning Resources	1. Mechanical Metallurgy, G. E. Dieter, McGraw Hill 2. Fatigue of Materials, S. Suresh, Cambridge University Press 3. Fundamental of Creep in Metals & Alloys, M. E. Kassner, Butterworth-Heinemann 4. Elements of Fracture Mechanics, Prasanta Kumar, McGraw Hill 5. Elementary Engineering Fracture Mechanics, David Broek, Kluwer Academic Publishers 6. Fracture Mechanics – Fundamentals and Applications, T. L. Anderson, CRC Press

Course Code	ME5207N	Course Name	Control of Mechanical Systems	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	1. To teach fundamentals of control system engineering 2. To teach how fundamental theories can be applied to control mechanical systems 3. To teach how different controllers can be designed and implemented for different objectives 4. To teach how and when to choose linear and nonlinear control 5. To teach simulation of control systems

Module	Topics	Duration (class-hour)	Module Outcome
Introduction	Closed-loop and Open-loop control Objectives of Control systems Examples of control systems Laplace Transform	05	Basic understanding of architectures and objectives of control system design
Modelling of Control Systems	Frequency domain modelling – Transfer function/Transfer Matrix Concept of Poles and Zeros Block Diagram Time Domain Modelling – State-space representation	08	Learning different methods of modelling Linear Time-invariant control systems
Response Analysis	Time-domain and Frequency-domain response of first, second and higher order systems	06	Learning to compute response of linear control systems
Characteristics of control systems	Sensitivity, Disturbance/Noise rejection, Steady-state accuracy, Stability analysis	07	Learning fundamentals characteristics of control systems
Design of controller	Pole-placement, PID, Internal Model Controller, LQR, LQG, Optimal Control, Adaptive control, Nonlinear control	06	Learning general rules of designing controllers
Controller Design for CNC and Robotic Devices	PID Control for CNC and Robotic Manipulator	04	Learning how to design controllers for important mechatronic systems
Vibration Control	Active Vibration Control	04	Learning control of vibration of mechanical systems
Total		**40**	

Course Outcome	1. Students will learn the basic objectives of control systems with examples 2. Students will be able to design controller algorithms for various objectives, especially for mechanical systems 3. Students will be able to simulate designed controller under different test conditions 4. Overall students will have moderate exposure to Mechatronic systems

Learning Resources	**Text Books:** 1. Control system Engineering – N. S. Nise , Wiley International Edition. Latest edition 2. Principles of Passive and Active Vibration Control – A. K. Mallik and S. Chatterjee, Affiliated East-West Press, New Delhi

Course Code	ME5208N	Course Name	Computational Mechanics of Solids	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	*Mechanics of Solids, Heat Transfer*	Co-requisite Courses	*Mathematics*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards	*Nil*		

Course Objective	1) To make students understand the various computational methods for solving structural and thermal problems 2) It aims to equip students with the knowledge and skills to apply finite element methods to analyze structural, thermal and other engineering problems. 3) To make students able to identify appropriate 1D, 2D, Axisymmetric problems for structural and thermal condition.

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction to Computation by Numerical Methods	Numerical Methods and its relevance in Engineering, Different Numerical Methods and their Utilities	02	Understand Various numerical methods
Fundamentals of FDM and FEM	Basic concepts of the FD and FE Methods and their Differences, Versatility of FE method over FD method.	01	Learn the basic concept of FD and FE Methods
Direct Stiffness Method: 1-D Springs	FE solution of assemblage of linear springs arranged in 1D. Element equations, assembly rule and imposition of BC. Solution and Calculation of support reactions. Problems.	03	Learn to formulate the Element equations and assembly finally applying the BC
Direct Stiffness Method: 2-D Truss	Extension of FE analysis of discrete systems from 1D to 2D: Analysis of Plane truss. Element equations, assembly rule and imposition of BC. Solution for displacements, member forces and support reactions. Special case of inclined roller supports. Problems on plane truss.	05	Understand and solve the problems of assemblage of springs/bars in1D and 2D truss.
Weighted Residual Method	Approximate solution of boundary value problems involving ODE by the weighted residual method. Weighted integral statement. Point collocation, Least-square, Rayleigh-Ritz and Galerkin procedure. Weak form: primary variables, secondary variables, essential BC, Natural BC. Advantages of weak form over strong form. Examples.	06	Learn to solve the boundary value problems involving ODE by the weighted residual method. Learn Rayleigh-Ritz and Galerkin procedure
FE Solution of 1-D boundary value problems	Solution of boundary value scalar field problem (such as heat transfer with surface convection and heat generation) depicted by ODE in 1-D. Deriving Shape functions of 1-D linear and quadratic elements. Natural coordinates. Weak form over a typical element. Element equation, assembly and solution for Primary and Secondary Variables. Variational method, Construction of functional (if exists) from the weak form of a	06	Learn the concept of shape functions, form the element equation, assembly and solution for primary and secondary variables in 1D boundary value problem

	problem.		
FE solution of beam problems	Review of Euler-Bernoulii beam equations. FE formulation of 1D beam problem governed by Euler-Bernoulli equation: Weak form, Galerkin procedure etc. Derivation of element equations, Assembly, Examples with different cases of supports, e.g., fixed, simple and distributed supports. Introduction to Frame elements.	05	Learn Euler-Bernoulii beam equations. FE formulation of 1D beam problems and solution for primary & secondary variables
FE formulation and solution of 2D steady state scalar field problems.	FE formulation of 2D scalar field problem, Weak form, Galerkin procedure, 3-node, 6-node triangular elements, Isoparametric formulation. Conforming and non-conforming elements while introducing 4-node and 8-node quadrilateral elements. Coordinate transformation, Jacobian, Parent and child elements.	06	Formulate the 2D scalar field problem. Isoparametric formulation for solving FE problems
FE solution of 2D steady state vector field problems	Stress analysis problems: Plane stress and plane strain type in 2D. Review of related equations. Variational formulation of thermo-elastic stress analysis problems and derivation of their functional. Solution of primary variables in the form of displacements and secondary variables in the form of stresses and reactions of supports	04	Learn variational formulation to solve 2D thermo-elasticity problems under plane stress and plane strain conditions
Demonstration of an FE commercial Package	Demonstration of an Finite Element Commercial package like ANSYS/ABAQUS/AUTODYN (any one).	02	Learn the commercial packages for solving the finite element problems
Total		**40**	

Course Outcome	At the end of the course, students should be able to 1. Grasp the fundamental concepts of the finite element method and its underlying principles. 2. Create and analyze finite element models of different systems and apply the method to solve various engineering and scientific problems. 3. Identify the application and characteristics of FEA elements such as bars, beams, plane and iso-parametric elements. 4. Implement the formulation techniques to solve two-dimensional problems using triangle and quadrilateral elements. 5. Formulate and solve Axi-symmetric and heat transfer problems using commercial Package.

Learning Resources	**Text Book** 1. Fundamentals of Finite Element Analysis, by David V. Hutton, Tata McGraw-Hill Publishing Co. Ltd., 2005. 2. A First Course in the Finite Element Method (5th Edition), by Daryl L. Logan, Cengage Learning, 2012.

	Reference Books 1. An introduction to the Finite Element Method (Third Edition), by J.N. Reddy, Tata McGraw-Hill, 2005. 2. Finite Element Analysis Theory and Application with ANSYS (4th edition), by Saeed Moaveni, Pearson, 2015. 3. Introduction to Finite Elements in Engineering, by T.R. Chandrupatla and A.D. Belegundu, Prentice-Hall of India Pvt. Ltd., 1991. 4. Finite Element Procedures, by K-J Bathe, Prentice Hall, Upper Saddle Rver, New Jersey 07458, 1996.

Course Code	ME5231N	Course Name	Introduction to Modern Materials	Course Category	PSE	L	T	P
						3	**0**	**0**

Pre-requisite Courses	*Mechanics of Solids*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		**Data Book / Codes/Standards**	*Nil*

Course Objective	The course ME5231 was designed with the following objectives in mind: 1. To make the students aware about the relevance and importance of alternative modern materials, distinctly different from conventional materials on a macro-scale, and made with the primary objective of weight saving as the premium. 2. To make the students aware about the engineered materials, particularly in view of having materials with high specific strength and high specific stiffness. 3. To intimate the students about importance of different types of composites and their usage to achieve the goal mentioned in (2), with a focus on fibre-reinforced composites. 4. To give a vivid exposure to the students about different aspects of FRP composite materials: classifications, knowledge of orthotropic materials, details about mechanics of FRP composites, failure criteria, ply-by-ply failure analysis etc. 5. Exposure to students on thermal and environmental effects on composites. 6. Giving exposure to students about different testing procedures of FRP composites. 7. Introducing the students to micro and nanocomposites. Special emphasis will be given to Gr-TPU, CNT-TPU and Gr-CNT-TPU type nanocomposites. 8. Giving the students a brief exposure to Molecular Dynamics Simulation using Materials Studio. 9. Training the students about computer implementation of analysis of composite laminates in MATLAB environment. 10. Giving the students an exposure to NDT and NDT of composites.

Module	Syllabus	Duration (class-hours)	Module Outcome
Modern/Alternative materials with an emphasis on Composite Materials: Definition, Classification	Modern Materials: Alternative materials with emphasis on FRP composites, Gr, CNT, TPU nanocomposites with examples, classification and comparison of properties with conventional metals.	03	Students get to know about (i) FRP composites, Nano-composites & (ii) classifications and comparison with conventional metals.
FRP Composites: Rules of Mixtures, Tsai- Halpin Equations	Volume and weight fractions, rule of mixtures, prediction of elastic constants, Tsai-Halpin equation for transverse properties, minimum and critical volume fractions.	02	Students get to know (i) terminologies, (ii) classifications, (iii) rule of mixtures and (iv) Halpin-Tsai guidelines.
Failure modes of Uni-directional Fibre-reinforced Composites	Failure modes in unidirectional fibre-reinforced composites: Due to tensile, compressive loads in the longitudinal direction, Due to similar loads in the transverse direction and due to shear load.	03	Students get to know about various failure modes of uni-directional fibre reinforced lamina under different types of loads.
Fabrication of Composite Materials	Manufacturing of composites: preparation of individual lamina leading to laminate casting, helical	02	Students get to know about manufacturing of composites in various shapes.

	winding, polar winding and pultrusion process.		
Constitutive Relations of Specially and Generally Orthotropic Laminae	Stress-strain relations of orthotropic lamina along principal material and arbitrary structural directions. Transformation of elastic constants.	05	Students learn constitutive relations of specially and generally orthotropic lamina.
Theories of Failure of Orthotropic Lamina	Theories of failure for orthotropic lamina, bi-axial strength theories: Maximum stress, Maximum strain, Tsai-Hill, Tsai-Wu theories of failure, Hashin Criteria of initial failure.	04	Students learn different theories of failure applicable for FRP composite lamina.
Environmental effects on composites	Environmental effects on composites: thermal and hygroscopic effects.	03	Students learn effects of temperature and humidity related changes on FRP composite lamina.
Analysis of Composite Laminates	Introduction to composite laminates, lamination code, Classical Lamination Theory (CLT) based on Kirchhoff's hypothesis, Relationship of {N}, {M} and $\{\varepsilon\}$, {k} in terms of [A], [B] and [D] matrices.	03	Students learn CLT and relationship between loads/moments {N}, {M} and mid-plane strains and curvatures $\{\varepsilon\}$, {k}.
Analysis of Composite Laminates (Contd.)	Specially orthotropic, generally orthotropic, symmetric, anti-symmetric and quasi-isotropic laminates.	03	Students learn various conditions for developing different types of laminates.
Design of Composite laminates	Design considerations via analysis of laminates after first ply failure, progressive failure of laminae in a composite laminate. Interlaminar stresses developed and possible delamination caused.	03	Students learn progressive failure mechanism of laminae in detail. They also learn interlaminar stresses developed in a laminate.
Property Determination of Composites by Tests	Experimental way of characterization of composites: tension, compression and various types of in-plane shear tests. Flexural tests. NDT of composites.	04	Students learn various test methods performed on lamina and laminates for estimation of properties. They also get an exposure on NDT.
Introduction to Nano-Composites	Nano-particles: platelets and nanotubes. Introduction to MWCNT, SWCNT, Graphene, Carbon-Carbon Composite, Bio-Composites, Introduction to fabrication of Gr-TPU nano-composites; Functionally Graded Materials, Composites in smart structures.	05	Students learn in detail concepts of nano-composites with nano-particles and their combination. Fabrication and modeling of Gr/CNT based nano-composites are also learnt.
Total		**40**	

Course Outcome	1. The students will learn about definition, classification, fabrication of composites in details. 2. They will learn the rules of mixtures, Halpin-Tsai equations, Calculations of various strengths and different modes of failures in composites. 3. They will be able to compute various stiffness matrices with the purpose to calculate lamina strains, stresses in principal material and structural directions and apply different theories for failure to check for failures of orthotropic laminae. 4. Students will learn in detail about laminate analysis, will be able to calculate lamina stresses and strains and assess life of laminates by estimating/checking ply-by-ply failure. 5. Students will be able to understand fundamental concepts of nanocomposites, model and analyze them on suitable software platforms.

Learning Resources	**Text Books:** 1. Analysis and Performance of Fiber Composites (Third Edition): Bhagwan D. Agarwal and Lawrence J. Broutman, K. Chandrasekhara, John Wiley & Sons, INC, 2006. 2. Mechanics of Composite Materials (Second Edition): Robert M. Jones Taylor & Francis, 1998. **Reference Books:** 1. Principles of Composite Material Mechanics (Third Edition): Ronald F. Gibson, CRC Press.

Course Code	ME5232N	Course Name	Bearing Lubrication	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Machine Design*	Co-requisite Courses	*Mathematics*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding of the lubrication in bearings. Various aspects like lubrication regime, journal bearings, thrust bearings, squeeze film bearings, *etc*. are thoroughly presented. Other aspects like instability, mechanisms of instability in hydrodynamic state, and elasto-hydrodynamic lubrication are addressed. In addition, special emphasis is given to applicability of gas bearings.

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Lubrication regime: Hydrodynamic lubrication, Elasto-hydrodynamic lubrication.	03	Presenting configurations of hydrodynamic and elasto-hydrodynamic lubrication.
02	Journal bearings: Deduction of basic governing equation (Reynolds Equation) for two dimensional flow, film geometry, half-Sommerfeld boundary condition, analysis of infinitely short and long journal bearings, numerical solution of Reynolds equation for finite journal bearings.	07	Understanding of journal bearings, associated governing equations, boundary conditions with concerned numerical techniques for solution.
03	Circular step thrust bearings: Analysis of capillary and orifice-compensated thrust bearings, optimum value of stiffness of both types of thrust bearings.	03	Addressing circular step thrust bearings and associated configurations.
04	Squeeze film bearings: Introduction on squeeze film bearings, its applications, basic equation for squeeze film, film pressure and load capacity estimation for infinitely long journal bearings, squeeze film lubrication between two long parallel plates, elliptical discs.	05	Presenting squeeze film bearings, pressure and load capacity estimation, and lubrication type.
05	Hydrodynamic instability: Introduction on hydrodynamic instability, mechanism of hydrodynamic instability and its preventive measure.	03	Understanding of hydrodynamic instability, its mechanisms and preventive measures.
06	Porous metal bearings: Introduction of porous journal bearings, applications, advantages of porous bearings over conventional journal bearings, Darcy's law for flow through porous journal bearings, deduction of governing equation, solution of governing equation for short journal bearings for film pressure and load capacity.	04	Addressing configurations of porous metal bearings, governing equation, and numerical solution techniques.
07	Elasto-hydrodynamic lubrication (EHL): Concept of EHL, EHL regimes, hydrodynamic equation of EHL, film shape and film pressure distribution, dimensionless design parameters for EHL point and line contacts, rolling contact bearings.	05	Presenting configurations of elasto-hydrodynamic lubrication, associated design parameters and rolling contact bearings.
08	Thermal effect on lubricated bearing film: Reynolds equation for thermo-hydrodynamic lubrication, energy equation, thermo-hydrodynamic analysis of Rayleigh step	04	Understanding of thermal effects on lubricated bearing film, Reynolds equation,

	bearings.		and concerned numerical solutions.
09	Gas bearings: Introduction on gas bearings, its applications, governing equation applicable to gas bearings, analysis of infinitely long journal bearing for low and high values of bearing number, solution of governing equation for two dimensional flow by perturbation method and linearized 'ph' method.	05	Understanding of gas bearings, concerned governing equations, and their solution methodologies.
	Total	**39**	

Course Outcome	At the end of the course, students should be able to 1. Understand various aspects of lubrication regime in hydrodynamic and elasto-hydrodynamic states. 2. Understand the aspects of journal bearings, thrust bearings, squeeze film bearings, porous metal bearings, and gas bearings. 3. Determine hydrodynamic instability and mechanisms of instability along with preventive measures. 4. Quantify thermal effects on lubricated bearing film. 5. Design bearings subject to the need.

Learning Resources	**Text Book** 1. Introduction to tribology of bearings - B. C. Majumdar (S. Chand & Company PVT. Ltd.) 2. Theory of Lubrication - B. C. Majumdar, M. K. Ghosh & M. Sarengi (Tata McGraw Hill Publication) 3. Applied Tribology: Bearing Design & Lubrication - M. M. Khonsari & E. R. Booser (J. Wiley & Sons Inc.) 4. The Principles of Lubrication - A. Cameron (Longmans, London)

Course Code	ME5233N	Course Name	Design of Piping Systems	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	This course deals with the details of rules and codes of industrial piping design. Starting from the piping stress analysis, this course will impart detailed knowledge about piping standards, piping joints, piping supports, transportation pipelines and vibration control in piping system.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	**Introduction**: Introduction to Piping Components and Connecting Equipment, Modes of Failure, Piping Codes basics	02	To make the students conversant on piping components, connecting equipment, piping standards, and modes of failure
2.	**Strength and Failure of Materials Basics**: Elastic Relationship of Stress and Strain, Plasticity, Creep, Fracture and fatigue	04	Stress strain analysis of piping stress; plasticity and creep; fracture and fatigue of pipelines in service
3.	**Piping Stress Analysis**: Codes and Standards, Design Consideration loadings, Basic Allowable stress, Pressure Design, Stresses of Piping Components	05	Design basis of pipelines and components based on international standards
4.	**Thermal Expansion and Piping Flexibility** Thermal Expansion Force and Stress, Methods of Providing Flexibility, General Procedure of Piping Flexibility Analysis, Problems With Excessive Flexibility.	07	To impart knowledge on thermal expansion and flexible design with actual problems
5.	**Expansion Joints**: Basic Flexible Joint Elements and Analytical Tools, Applications of Bellow Expansion Joint, Slip Joints and Flexible Hoses	02	Give detail overview of different types of flexible joints and some design calculation.
6.	**Pipe Supports and Restraints**: Analysis of Piping Systems Resting on Supports, Support of Long Risers, Significance of Support Friction, Pipe Stresses at Integral Support Attachments	05	As piping supports are an integral part of piping systems, students must learn about different types of supports and their design basis
7.	**Piping connected to Rotating Equipment** Pipe Connected to Steam turbines, Centrifugal Compressors, Centrifugal Pumps, Procedure for Designing Rotation Equipment Piping.	05	To learn about the critical piping design for rotating equipment like steam turbine as it involves very high pressure.
8.	**Transportation Pipeline**: Governing Codes and General Design Requirements, Behavior of Long Pipeline, Pipeline Bends	03	To learn about the design codes and its basis for long pipelines like cross-country pipelines for crude oil.
9.	**Vibration control in piping**: Fundamental Consideration in piping vibration, Structural	07	To impart knowledge on vibration control of high-pressure pipelines

	Natural Frequency Calculation, Damping of structural vibration, Flow pulsation Smoothing, Illustration of Vibration analysis of a simple Piping System		depending on the fluid flow system also by some simple numerical examples.
	Total	**40**	

Course Outcome	Students will have detail knowledge about piping design as per international design codes. Hey will be able to sort out the problems in the piping system more easily. With this course, the students will be more confident to work in the process industry e.g., petrochemical. refinery, power plant.

Learning Resources	**Text books:** 1. Pipe Stress Engineering, by Liang-Chuan Peng and Tsen-Loong Peng, ASME Press. 2. Introduction to Pipe Stress Analysis, by San Kannappan, John Wiley & Sons. 3. Design of Piping Systems, by M.W.Kellogg Company, Blurb, 2019. 4. Piping Design Handbook, by John J Mcketta, CRC Press, 1992.

Course Code	ME5234N	Course Name	Non-Destructive Testing of Materials	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards	*Nil*		

Course Objective	The goal of the course is to provide students with the knowledge and skills to effectively utilize NDT techniques for the detection, assessment, and documentation of material flaws, ultimately contributing to the safety and reliability of various industries. Mainly to inspect a component in a safe, reliable, and cost effective manner without causing damage to the equipment or shutting down plant operations.

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction	Introduction to NDT, Comparison between destructive and NDT, Importance of NDT, Scope of NDT, difficulties of NDT, future progress in NDT, economics aspects of NDT.	02	Learn basic concept and basic need for NDT
Visual Inspection	Visual Inspection tools, applications and limitations - Fundamentals of visual testing: vision, lighting, material attributes, environmental factors, Visual perception, direct and indirect methods mirrors, magnifiers, boroscopes, fibroscopes, closed circuit television, light sources, special lighting systems, computer enhanced system.	04	Accustomed with various simple NDT test methods
Penetrant Inspection	Dye penetrant Testing/ liquid penetrant testing: Principle, procedure, types & characteristics of penetrants and developers, penetrant testing materials, fluorescent penetrant testing, interpretation and evaluation of penetrant test indications, false indication and safety precaution required in Penetrant Inspection, applications, advantages and limitations of various methods of Penetrant Inspection technique/ test.	05	Learn various dye penetrant and liquid penetrant testing. Their application in the various industrial need.
Magnetic Particle Inspection (MPI)	Principles of MPI, basic physics of magnetism, permeability, flux density, cohesive force, magnetizing force, rentivity, residual magnetism Methods of magnetization, magnetization techniques such as head shot technique, cold shot technique, central conductor testing, magnetization using products using yokes direct and indirect method of magnetization, continuous testing of MPI, residual technique of MPI, system sensitivity, checking devices in MPI Interpretation of MPI, indications, advantage and limitation of MPI.	05	Learn in details about the magnetic particle inspection for ferrous components. Inspection after fabrication and health monitoring purposes.

Ultrasonic Testing (UT)	Principle, types of waves, frequency, velocity, wavelength, reflection, divergence, attenuation, mode conversion in ultrasonic UT testing methods contact testing and immersion testing, normal beam and straight beam testing, angle beam testing, dual crystal probe, ultrasonic testing techniques resonance testing, through transmission technique, pulse echo testing technique, instruments used UT, accessories such as transducers, types, frequencies, and sizes commonly used Reference blocks with artificially created defects, calibration of equipment, Applications, advantages, limitations, A, B and C scan - Time of Flight Diffraction (TOFD).	07	Get detailed idea about various ultra-sonographic testing. For various materials across different applications. The advantages and limitations of these technique
Radiography Testing (RT)	Principle, electromagnetic radiation sources: X-ray source, production of X-rays, high energy X-ray source, gamma ray source - Properties of X-rays and gamma rays Inspection techniques like SWSI, DWSI, DWDI, panoramic exposure, real time radiography, films used in industrial radiography, types of film, speed of films, qualities of film screens used in radiography, quality of a good radiograph, film processing, interpretation, evaluation of test results, safety aspects required in radiography applications, advantages and limitations of RT.	07	Learn various X-Ray source for radiographic testing. Learn the various inspection methods like SWSI, DWSI, DWDI, panoramic exposure, real time radiography for industrial application for nondestructive testing during.
Infrared Thermography Testing	Introduction and fundamentals to infrared and thermal testing, Heat transfer, Active and passive techniques, Lock in and pulse thermography, Contact and non-contact thermal inspection methods, Heat sensitive paints and papers, thermally quenched phosphors liquid crystals, techniques for applying liquid crystals & other temperature sensitive coatings, Inspection methods, Infrared radiation and infrared detectors, thermo mechanical behavior of materials, safety aspects, applications, advantages and limitations of Infrared Thermography testing.	06	Learn the basic principle of Infrared Thermography. Their specific application for high temperature environment. Various inspection methods, result interpretation and specific applications
Eddy Current Testing (ECT)	Principle, physics aspects of ECT like conductivity, permeability, resistivity, inductance, inductive reactance, impedance Field factor and lift of effect, edge effect, end effect, impedance plane diagram in brief, depth of penetration of ECT, relation between frequency and depth of penetration in ECT equipments and accessories, various application of ECT such as conductivity measurement, hardness measurement, defect detection coating thickness measurement, advantages and limitations of eddy current testing.	06	Understand the basics of Eddy Current Testing. Applications of various ECT for conductivity measurement, hardness measurement, defect detection coating thickness measurement and their merits and demerits
	Total	**42**	

Course Outcome	At the end of the course, students should be able to 1. Classify various NDT methods, understand and apply specific NDT techniques like liquid penetrant, magnetic particle, ultrasonic, and radiographic testing, and effectively communicate and document their findings. 2. Differentiate various defect types and select the appropriate NDT methods for accurate evaluation. 3. Interpret results from common NDT methods such as liquid penetrant testing (LPT), magnetic particle testing (MPT), ultrasonic testing (UT), and radiography (RT), Infrared Thermography. 4. Identify different types of material defects and choose the most appropriate NDT method for evaluating them.

Learning Resources	**Text Book** 1. Prasad, J. and Nair, C. G. K., Non-Destructive Test and Evaluation of Materials, Tata McGraw-Hill Education, 2nd edition (2011). 2. Rangachari, T., Prasad, J. and Murthy, B.N.S., Treatise on Non-destructive Testing and Evaluation, Navbharath Enterprises, Vol.3, (1983). **Reference Books** 1. Paipetis, A.S., Matikas, T. E and Aggelis D. G., Emerging Technologies in Non-Destructive Testing, CRC Press, (2012). 2. Raj, B., Jayakumar, T. and Thavasimuthu, M., Practical Non Destructive Testing, Alpha Science International Limited, 3rd edition (2002).

Course Code	ME5235N	Course Name	Industrial Tribology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Machine Design*	Co-requisite Courses	*Mathematics*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding of the tribology in broad sense especially in purview of industrial aspects. Different surface treatment procedures including lubrication, Ferrography, *etc*. are addressed. Emphasis is given to tribology in industry applications, biomedical engineering, and eco-friendly lubrication. Different techniques for understanding the phenomena of tribology through sophisticated instruments are also presented.

Module	Syllabus	Duration (class-hour)	Module Outcome
01	Surface engineering: Surface treatments - micro-structural and thermo-chemical treatments, and surface coatings - hard facing and vapour deposition processes.	05	Understanding of surface treatments and coatings
02	Liquid lubricants and additives – properties and measurement: Synthetic lubricants, greases, viscosities of Newtonian and Non-Newtonian fluid, viscometers, viscosity index, effect of temperature, pressure and shear rates on viscosity, flash point, pour point, specific heat and thermal conductivity of lubricants, anti-wear & anti-foam additives, and detergent and dispersant additives.	08	Addressing lubricants and additives, their properties, and measurement configurations.
03	Boundary lubrication: Mechanism of boundary lubrication, metal-working lubrication, solid film lubrication, and solid lubricants.	05	Understanding of boundary lubrication, mechanisms, solid film lubrication, and lubricants.
04	Tribology in industry: Tribology in automotive engineering and coal-fired power plants, and case studies of tribo-failures.	05	Addressing aspects of tribology in various applications.
05	Wear debris analysis: Ferrography and Spectrometric Oil Analysis Program (SOAP).	04	Presenting methodology of wear debris analysis through ferrography and SOAP.
06	Tribology in biomedical engineering: Lubrication in natural synovial joints, synthetic cartilage and lubricants, design of joints and prosthetic devices, and biomaterials.	07	Addressing tribology aspects in biomedical engineering.
07	Nano-tribology: Surface Force Apparatus (SFA), Scanning Tunneling Electron Microscope (STM), Atomic Force Microscope/Friction Force Microscope (AFM/FFM), and fabrication techniques for MEM/NEMS.	04	Understanding of nano-tribology through instruments like STM, AFM, *etc*.

08	Green tribology: Biomimetics for tribological applications, surface texturing, and environment-friendly lubrication (self, natural and biodegradable lubrication).	04	Addressing green tribology with biomimetics and surface engineering.
	Total	**42**	

Course Outcome	At the end of the course, students should be able to 1. Understand various aspects of surface treatment, lubrication, viscosity of fluids, *etc*. 2. Understand the aspects of tribology in industries especially in automotive sector and biomedical engineering. 3. Characterize tribology with the aid of different sophisticated instruments. 4. Characterize surface morphology through surface texturing. 5. Employ green tribology by means of utilizing environment-friendly lubrication and following biomimetics.

Learning Resources	**Text Book** 1. Engineering Tribology - G. W. Stachowiak and A. W. Batchelor, Elsevier Science, Elsevier **Reference Books** 1. Microstructure and Wear of Materials - Karl-Heinz Zum Gahr, Elsevier Science Publishers 2. Engineering Tribology – Prasanta Sahoo, Prentice-Hall of India Pvt. Ltd., 2005 3. Tribology and Mechanics of Magnetic Storage Devices - Bharat Bhushan, Springer-Verlag 4. Tribology in Machine Design - T. A. Stolarski, Heinemann Newness 5. Lubrication and Lubricants - Eric R. Braithwaite 6. Wear Control Handbook - M. B. Peterson and W. O. Winer, ASME 7. Tribology Handbook - M. J. Neale, Butterworth-Heinemann

Course Code	ME5236N	Course Name	Data-Driven Dynamical Systems	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Linear and Nonlinear Vibration*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	This course is about gaining understanding about any dynamical system through data. 1. To make the students aware of the fact that the equations of motion (EOMs) are generally analyzed to gain understanding of that system 2. The EOMs of the pendulum systems will be analyzed to gain understanding which can be extended to any dynamical systems 3. Evolution of discrete dynamical systems will be taught through maps 4. In the absence of EOMs and Maps, Systematic modelling of the systems using Data will be taught 5. Reduced order modelling will be taught for both classical and Data-Driven systems 6. Application of different techniques through Machine Learning will be taught

Module	Syllabus	Duration (class-hours)	Module Outcome
Introduction	What is Dynamical System? Flows and Maps.	02	The students will have comprehensive understanding of dynamical systems in terms of flows and maps
Derivation of Equations of Motion	Simple, Externally Forced and Parametrically Pendulum (SDOF), Double Pendulum (2DOF)	03	The students will be able to derive equations of motion of different systems with a main focus to pendulum based systems
Linear and Nonlinear Systems	State-space, Fixed Point, Linear Stability Analysis, Limit Cycle.	06	The students will gain brief understanding of linear and nonlinear systems. They will be able to analyze linear/nonlinear systems with limited techniques
Introduction to Chaos	One Dimensional Map: Fixed Points and their Stability. Numerics with Logistic Map, Lorenz Equations. Definition of Chaos, Lyapunov Exponent, Poincaré Map.	05	The students will have brief understanding of chaos. They will be able to apply certain techniques to analyze chaos
Dynamics of a Few Systems	SDOF Pendulum (Simple, Externally Forced, Parametrically), Forced Duffing Oscillator	07	The students will gain comprehensive understanding of the dynamics of simple and forced pendulum and forced Duffing oscillator

Classical Reduced Order Modeling	Singular Value Decomposition, Galerkin Projection, Proper Orthogonal Decomposition	04	The students will be able to model reduction by applying classical techniques
Importance of Data	Non-availability of Mathematical Models, Basic Idea of Machine Learning	05	The students will have basic understanding of machine learning
Data-Driven System Identification	Sparse Identification of Nonlinear Dynamics (SINDy), SINDy using Neural Network	03	The students will be able to apply SINDy
Data-Driven Reduced Order Modeling	Dynamic Mode Decomposition (DMD), DMD using Neural Network	03	The students will be able to apply DMD
Linear Embedding of Nonlinear Dynamics	Koopman Spectral Analysis, Koopman Spectral Analysis using Neural Network	04	The students will be able to apply Koopman Spectral Analysis
Total		**42**	

Course Outcome	1. The students must have clear idea about the difference among Differential Equations, Maps and Data-Driven modelling. The students must also learn the necessity of these three methods 2. The students must be able to analyze the systems using the EOMs or the Maps where they are available. 3. The students must be able to do reduce order modelling 4. The students should have reasonable ideas and understanding about SINDy, DMD and Koopman analysis 5. The students must be able to write Machine Learning codes related to this course

Learning Resources	**References**: 1. S. H. Strogatz, Nonlinear Dynamics and Chaos, Addison-Wesley, Reading, MA, 1994. 2. R. H. Rand, Lecture Notes on Nonlinear Vibrations. (http://audiophile.tam.cornell.edu/randdocs/nlvibe52.pdf) 3. D. W. Jordan and P. Smith, Nonlinear Ordinary Differential Equations, Oxford University Press, New York, 1999. 4. J. Nathan Kutz and Steven L. Brunton,Data-Driven Science and Engineering: Machine Learning, Dynamical systems, and Control, 2nd Edition, Cambridge University Press, 2022.

Course Curriculum
for
Advanced Manufacturing Technology

Course Code	ME5111N	Course Name	Industrial Engineering	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	To impart advanced knowledge on Industrial Engineering, concept of Productivity and work study, production budget preparation To make familiar about facility layout and planning, systems of production planning and control and technics of inventory management.

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction	Concept of Industrial Engineering, Scope of Industrial Engineering, tools of management science, Managerial economics and accounting.	02	Understand importance of Industrial Engineering in Industry
Production & Productivity	Production function and system, Input output model, Micro-Economics applied to the plant and industrial undertaking, Productivity, factors affecting the productivity, productivity improvements & Measurement of productivity.	03	Impart knowledge about productivity enhancement
Plant Location Layout & Line Balancing	Factors affecting the plant location, Types of layout and its characteristics, Work station Design, Procedure of layout, factory building construction & design, Different concepts of line balancing.	05	Understand various types of plant layout and their advantages
Work Study	Concept of work study, Method study procedure, Flow charts, Multiple activity chart, micro-motion, principles of motion economy, Design of workplace layout, Therbligs, SIMO chart, Work measurement - Stopwatch time study procedure, performance rating & allowances, standard data, numerical problems, PMTS, MTM, work factor, work sampling, Wage incentives and collective bargaining, Ergonomics	12	Impart knowledge about the concept of work study
Plant Maintenance & replacement	Objective, importance & classification of plant maintenance, Duty, function and responsibility of plant maintenance department, Breakdown, schedule, preventive and predictive maintenance, Plant maintenance Schedule and recent development. Reasons and factors of replacement, methods used for selection of	07	Learn about various plant maintenance techniques

	Alternatives		
Cost Accounting & Control	Introduction, elements, nature & type of cost, factory cost, total cost, selling price, allocation of overhead, control and accounting of material, labour and overhead, Depreciation, Breakeven analysis and Charts.	07	Impart knowledge about production cost control
Budget & Budgetary Control	Concept of budget, budgeting and budgetary control, its advantage, limitation and classification, Preparation of budget, Budget as a means of planning, control and coordination, Working of budgetary control.	06	Familiar with the production budget preparation and their control techniques
	Total	**42**	

Course Outcome	At the end of the course, the student will be able to: 1. Understand the concepts of Industrial Engineering. 2. Explain production systems and their characteristics. 3. Understand the role of productivity in streamlining a production system. 4. Describe different aspects of work system design and facilities design pertinent to manufacturing industries 5. Apply forecasting and scheduling techniques to production systems. 6. Apply the inventory management tools in managing inventory

Learning Resources	**Text Books:** 1. Kumar, B., Industrial Engineering & Management, Khanna Publication, ISBN-8174091963, 2011. 2. Kumar, P., Industrial Engineering and Management, Pearson Education, 1st edition, ISBN-9789332543560, 2015. **Reference Books:** 1. Khanna, O. P., Industrial Engineering & Management, Dhanpat Rai Publication, 19th edition 2013

Course Code	ME5112N	Course Name	Non-Traditional Machining	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	Nil

Course Objectives	The course aims in • Understanding the need of Non-Traditional Machining in the present industrial scenario. • Understanding the principle, mechanism of material removal of various Non-Traditional Machining processes. • Studying the various process parameters and their effects on the machined components. • Understanding different Hybrid manufacturing processes. • Elucidation of the applications of different processes.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Need of Non-traditional manufacturing in the present industrial scenario. Differences between traditional and Non-traditional manufacturing, Classification of Non-traditional manufacturing processes.	04	• Understanding the basics of Non-traditional manufacturing processes.
II	Introduction to impact erosion processes, Abrasive Jet Machining (AJM): Process principles, Machining set-up, Operating parameters, Modelling of Material Removal Rate (MRR), Advantages, Limitations, Different applications.	06	• In-depth knowledge on principle, analysis and applications of AJM process.
III	Water Jet Machining (WJM): Equipment, Process principles, Operating parameters, Advantages, Limitations, Different applications.	04	• Comprehensive knowledge on principle, analysis and applications of WJM process.
IV	Ultrasonic processing of materials, Ultrasonic Machining (USM): Operating Principle, Machining set-up, Operating parameters, Horn design, Modelling of Material Removal Rate (MRR), Advantages, Limitations, Applications of Ultrasonic processing.	04	• Thorough knowledge on principle, analysis and applications of USM process.
V	Chemical Machining (CHM): Equipment, Process principles, Maskants and etchants, Photo-Chemical Machining Advantages, Limitations, Different applications.	04	• Comprehensive knowledge on principle, analysis and applications of CHM process.
VI	Electro-Chemical Machining (ECM): Equipment, Process principles, Operating parameters, Modelling of Material Removal Rate (MRR), Dynamics of ECM, Advantages, Limitations, numerical problems on ECM, applications.	04	• In-depth knowledge on principle, analysis and applications of ECM process.

VII	Electro-Discharge Machining (EDM): Equipment, Process principles, Operating parameters, Modelling of Material Removal Rate (MRR), numerical problems on EDM, Wire-Electro-Discharge Machining Process (WEDM), Advantages, Limitations, applications.	06	• In-depth knowledge on principle, analysis and applications of EDM and WEDM process.
VIII	Fundamentals of Laser Beam Machining (LBM), lasing process, Material processing with laser; Fundamentals of Electron Beam Machining (EBM), Process principles, Applications.	06	• Comprehensive knowledge on principle, analysis and applications of LBM and EBM processes.
IX	Introduction to Hybrid machining, Electro-Chemical Grinding (ECG), Abrasive Water Jet Machining (AWJM), Vibration assisted hybrid machining processes, Magnetic field assisted machining processes.	04	• Comprehensive knowledge on different Hybrid machining processes.
Total		**42**	

Course Outcome	After successful completion of the course, the student shall be able to • Understand the principle of working, mechanism of material removal in the various Non-traditional machining processes. • The student shall also be able to identify the process parameters, their effects and applications of different Non-traditional processes.

Learning Resources	**Text Books:** 1. Non-conventional Machining by P. K. Mishra, Narosa Publishing House. 2. Nontraditional Manufacturing by G. F. Benedict, Marcel Dekkar Inc. 3. Modern Machining Processes by P.C. Pandey and H.S. Shan, Tata McGraw-Hill Publishing Company Limited. **Reference Books:** 1. Laser Material Processing by W.M. Steen, Springer-Verlag. 2. Production Technology, HMT, Tata McGraw-Hill Education

Course Code	ME5113N	Course Name	Advanced Material Processing Technology	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	To impart knowledge on the material behaviour subjected to different manufacturing processes, different types of conventional manufacturing techniques such as casting, welding, powder metallurgy etc. This course will also include the scope of micro and macro manufacturing.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	An Introduction on the behavior, characterization, application and mechanical properties of various engineering materials. An overview on the latest (updated) advanced materials used in manufacturing industry. Manufacturing properties of metals and non-metals	04	Basic idea about various advanced material processing technologies
2.	Casting process – Metal fluidity, flow, Principle of gating system design, gating system design, Various elements of a rating system, risering – solidification – Thermal effects – Different casting processes – Design of castings – Plant and equipments – Quality Control - Defects in castings-Application of casting in manufacturing, Problems on Casting	12	Impart advanced knowledge about casting processes
3.	Welding processes – Welding metallurgy – Residual stresses – Thermal and allied problem – Plant &equipments – Welding tests – Welding Design- Modern welding & cutting processes – Welding defects – Application of welding in manufacturing, Problems on Welding	12	Impart advanced knowledge about various industrial welding processes
4.	Powdered Metallurgy – An Introduction on powder metallurgy technique, Production of powdered metals, Compactional, Sintering – Equipment for powder metallurgy – Machines & powdered products, Application of powder metallurgy technique in manufacturing	08	Impart knowledge about powder metallurgy process
5.	Micro Manufacturing (MM) - Introduction to Micro manufacturing (Micro machining and Micro fabrication), A brief overview on different micro manufacturing processes, Advantages,	04	Impart knowledge about various micro manufacturing technologies

	Limitations, applications		
	Total	**40**	

Course Outcome	Students will have specific knowledge on the material behaviour subjected to different manufacturing processes, different types of conventional manufacturing techniques such as casting, welding, powder metallurgy etc. This course will also include the scope of micro and macro manufacturing.

Learning Resources	**Text book** 1. Manufacturing Technology (Foundry, Forming and Welding) – by P N Rao, Tata McGraw-Hill (I) Publishing Company Limited, New Delhi. 2. Manufacturing Science by A. Ghosh and A. K. Mallick, 2e, Affiliated East-West Press Pvt. Ltd. 3. Welding and Welding Technology by Richard L Little, Tata McGraw-Hill (I) Publishing Company Limited, New Delhi. **Reference book** 1. Laser Material Processing by W.M. Steen, Springer-Verlag. 2. Modern Machining Processes by P.C. Pandey and H.S. Shan, Tata McGraw-Hill Publishing Company Limited. Production Technology, HMT, Tata McGraw-Hill Education

Course Code	ME6141N	Course Name	Machine Learning for Mechanical Engineers	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	1. Mathematics I (MA-1101) 2. Introduction to Computing (CS-1101) 3. Mathematics II (MA-1201) 4. Mathematics III (MA-2101) 5. Numerical Methods in Engineering (ME-2102) or, equivalent subjects	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	**Data Book / Codes/Standards**	*Nil*		

Course Objective	To impart knowledge on the following topics: 1. ***Define*** the conventional as well as modern input-output modelling tools, various types of optimization techniques and its real-life implementation into different types of engineering applications. 2. ***Illustrate*** the basic architecture and working mechanism of the different machine learning algorithms. 3. To ***solve*** the numerical to determine the nature of working of the input-output models. 4. ***Modelling*** and optimization using real-life solved example problems.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Introduction to Artificial Intelligence and machine learning; Advantages, need and limitations; Definition of Soft Computing; Difference between Hard and Soft Computing; Domain soft computing techniques; Different types of Learning Algorithms, Universal Approximation Theory, Introduction to Fuzzy Systems, Artificial Neural Network, Genetic Algorithm, Hybrid Systems;	05	***Define*** the basics of artificial intelligence, hard and soft computing, modelling and optimization (CO1).
2	Artificial Neural Network (ANN): Basic NN Architectures, Different types of ANN, ANN Training methods, Neural Differential equations, Learning algorithms and paradigms, Learning, Single layer and multilayer perceptions, back propagation network, SOM, Radial basis Function Networks, Elman-Jordan Recurrent Neural Networks, Convolutional and Deep Neural Network and related algorithms	07	***Discuss*** the architecture and working of ANN, RNN, associated differential equations etc. (CO2). ***Examine*** related input-output problems etc. (CO4).
3	Crisp and Fuzzy Set, Membership function, Fuzzy logic controller: Mamdani Approach, Takagi and Sugeno's Approach, Fuzzy Clustering.	06	***Recogniz e***the basics of fuzzy sets, clustering approaches (CO1) ***Discuss*** the equipment needed for the material handling system (CO2). ***Solve*** numerical on Fuzzy modeling (CO3).

4	Hybrid Neuro-Fuzzy modelling, other modelling techniques: Decision trees, Random Forest, Support vector, Lazy Learners etc.	06	***Extend*** knowledge on other modeling techniques (CO2).
5	Optimization, Single, Multi and Many Objective Optimization, Pareto Optimal Front, Non-dominated Sorting Genetic Algorithms (NSGA)	04	***Explain*** the working of single, multi and many objective optimizations (CO2).
6	Nature Inspired Metaheuristic Optimization Techniques: Genetic algorithms (GAs), GA operators: Crossover, Mutation etc., Simulated annealing etc., Swarm Intelligence based techniques (Particle Swarm Optimization, Firefly algorithm, Flower pollination algorithm, Crow search algorithm etc.)	06	***Show*** the working of a few metaheuristic algorithms, working principles, and associated equations (CO3). ***Test*** problems on GA, PSO etc. (CO4).
7	Modelling and Optimization with Some Practice and Assignments	05	***Examine*** modelling and optimization problems etc. (CO4).
Total		**39**	

Course Outcome	After this course, the students will have specific knowledge/skill set: 1. ***Define*** the different input-output modelling techniques, their working principles, and their real-life implementation into different types of engineering applications. 2. ***Illustrate*** the architecture and working mechanism of the different modelling and optimization algorithms. 3. To ***solve*** the numerical and establishment of the input-output models. 4. Real-life ***modelling*** and optimization using provided dataset.

Learning Resources	**Text book** 1. Soft Computing and AI: Fundamentals and Applications by Dilip K. Pratihar, Narosa Publishing House Pvt. Ltd., New Delhi, 2025 2. Neural networks A comprehensive foundations, Simon Haykin, Pearson Education 2nd Edition 2004 3. Neural Fuzzy Systems- A Neuro-Fuzzy Synergism to Intelligent System, C.T. Lin and George Lee, Prentice Hall 4. Genetic Algorithms in Search, Optimization and Machine Learning, David E. Goldberg, **Reference book** 1. Artificial neural networks by B.Vegnanarayana Prentice Halll of India P Ltd 2005 2. Neural networks in Computer intelligence, Li Min Fu TMH 2003 3. Neural networks, James A Freeman David M S kapura Pearson Education 3. An Introduction to Genetic Algorithms, Melanie Mitchell, MIT Press. 4. Uncertain Rule-Based Fuzzy Logic Systems: Introduction and New Directions, Jerry M. Mendel, 5. Fuzzy Logic with Engineering Applications, Timothy. J. Ross

Course Code	ME5142N	Course Name	Design of Production System	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	*Nil*

Course Objective	To impart knowledge on the following topics: 1. ***State*** the basics of operation management process, its pros, cons and application areas, the scope of CIMS and FMS, idea on production planning, scheduling, cost accounting and financial statements 2. ***Illustrate*** the different types of production systems, product life cycle, the techniques of resource planning, features of an inventory management system etc. 3. ***Demonstrate*** the different forecasting techniques, basics of cellular manufacturing systems, layout design, ***solve*** numerical on sequencing etc. 4. ***Point out*** the mechanism of decision-making utilizing decision tree algorithms.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.Introduction	Operations Management: meaning and scope; Significance of operations management in increasing productivity of firms; Types of production systems, scope; characteristic features, and applications, product life cycle, concurrent engineering.	06	***Describe*** basics and scope of operation management process, its pros, cons etc. (CO1). ***Explain*** the types of production systems, product life cycle etc. (CO2).
2.Facility Design	Facility location factors and evaluation of alternate locations; types of plant layout and their evaluation; line Balancing & G.T, cellular manufacturing systems; computer aided layout design techniques; assembly line balancing; materials handling systems.	05	***Classify*** the plant layout, material handling systems etc.(CO2). ***Examine*** the basics of cellular manufacturing systems, techniques of layout design etc. (CO3)
3.Forecasting Analysis	Need and benefits; Internal and external factors affecting demand; Types of forecasting models based on time horizon; Types of forecasting based on techniques (causal, time series and judgmental methods); Error analysis.	04	***Demonstrate*** the working and usages of different forecasting techniques, error estimation etc.(CO3).
4.Production Planning	CIMS & FMS: Problem of planning and control in CIMS and FMS; Aggregate production planning; Function and scope; Pure and mixed aggregate planning strategies; Aggressive and reactive strategies. Resource allocation, Project scheduling, Capacity Planning Scheduling & Sequencing Machine assignment and allocation of jobs. Sequencing problems. Flow shops scheduling and sequencing. Simulation of job shop priority rules. Gantt charts, production	10	***Define*** the scope of CIMS and FMS, scope of production planning, scheduling etc. (CO1). ***Explain*** the techniques of resource planning (CO2) ***Solve*** numerical related to input-output estimation, sequencing etc. (CO3)

	control with LOB.Master production scheduling; Function and scope; Inputs for master production scheduling; Types of master production schedules. Material requirements planning; Function and scope; Inputs for Materials requirement planning; MRP explosions; Manufacturing resource planning.		
5.Inventory Management and Control	Inventory: need and types, deterministic and stochastic models for inventory management.	08	***Describe*** the features and requirement of an inventory management system (CO2).
6.Decision Theory	Structure of the problem (decision table); Decision making under uncertainty with optimistic, pessimistic and average outcome criteria; Decision making under risk with expected value and expected loss criteria; Sequential decision using decision trees.	04	***Recognize*** the uncertainties and risk associated with decision making, loss estimation etc. (CO2). ***Examine*** the influence of decision making through the use of decision tree algorithms (CO4)
7.Engineering Economy and Costing	Elementary cost accounting and methods of depreciation; break-even analysis, techniques for evaluation of capital investments, financial statements	03	***Recognise*** the basics of cost accounting, financial statements etc. (CO1).
	Total	**40**	

Course Outcome	After this course, the students will have specific knowledge/skill set: 1. ***Outline*** the operation management process, its advantages, limitations and usage areas, the introduction to CIMS and FMS, idea on production planning, scheduling, cost accounting and financial statements. 2. ***Classify*** the types of production systems, product life cycle, the methods of resource planning, basics of inventory management system etc. 3. To ***show*** the basics of cellular manufacturing systems, layout design, solve numerical on sequencing, state different forecasting techniques. 4. ***Construct*** decision tree models to formulate the decision-making process.

Learning Resources	**Text book** 1. 1. Boeuf, M. L., "Essence of Time Management", Jaico Publication House, 1995 2. 2. Gupta A.K., Sharma S.J, "Management of System" 3. Chase Richard B, Operations Management, 11th edition Tata McGrawhil

Course Code	ME5143N	Course Name	Industrial Automation	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding of advanced automation, material handling, automated manufacturing systems, and control technologies. Aspects of modelling and simulation for plant automaton are discussed. Different control applications in industries are discussed.

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction	Automation in Production System, Principles and Strategies of Automation, Basic Elements of an Automated System, Advanced Automation Functions, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines.	07	Understanding of automation in industries, characters and fundamentals of transfer lines.
Material handling and Identification Technologies	Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems, Overview of Automatic Identification Methods.	05	Understanding of material handling methods and equipment.
Automated Manufacturing Systems	Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, GT and Cellular Manufacturing, FMS, FMS and its Planning and Implementation. Quality Control Systems: Traditional and Modern Quality Control Methods, SPC Tools, Inspection Principles and Practices, Inspection Technologies.	07	Presenting automated manufacturing systems along with FMS and different quality control systems.
Control Technologies in Automation	Industrial Control Systems, Process Industries Versus Discrete-Manufacturing Industries, Continuous Versus Discrete Control, Computer Process and its Forms.	05	Addressing control technologies in automation applied by industries.
Computer Based Industrial Control	Introduction & Automatic Process Control	03	Addressing methodologies of automatic process control.
Building Blocks of Automation Systems	LAN, Analog & Digital I/O Modules, SCADA Systems& RTU	03	Addressing methods of LAN, analogue & digital modules, *etc*.
Distributed Control System	Functional Requirements, Configurations & some popular Distributed Control Systems	04	Presenting configurations of distributed control systems.
Modeling and Simulation for	Introduction, need for system Modeling, Building Mathematical Model of a Plant, Modern Tools	04	Addressing configurations of

Plant Automation	&Future Perspective		modelling and simulations required for a plant establishment.
Industrial Control Applications	Cement, Thermal, Water Treatment & Steel Plants	03	Understanding of different control applications employed by industries.
	Total	**41**	

Course Outcome	At the end of the course, students should be able to 1. Understand automation in industries, characters and fundamentals of transfer lines. 2. Understand material handling methods and equipment. 3. Perceive about automated manufacturing systems along with FMS and different quality control systems. 4. Implement methodologies of automatic process control. 5. Understand configurations of distributed control systems. 6. Comprehend configurations of modelling and simulations required for a plant establishment. 7. Understand different control applications employed by industries.

Learning Resources	**Text Books:** 1. Automation, Production Systems and Computer Integrated Manufacturing M.P. Groover, Pearson Education.5th edition, 2009

Course Code	ME5144N	Course Name	Quality Engineering	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding of quality concepts, cause-effect relationship, different statistical tools, and quality aspects in design-standardization. Statistical process controls, sampling plans, quality in packing, installation and maintenance are addressed. Reliability aspects are introduced along with design of experiments techniques, Industry 4.0, and quality loss functions.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Quality Concepts and Scope; Quality of Design and Quality of Manufacturing; Quality Costs and Analysis.	04	Understanding of quality concepts, scopes and analysis procedures.
2	Quality Analysis-Cause-Effect Relationship, Ishikawa Diagram.	02	Addressing cause-effect relationship and Ishikawa diagram.
3	Statistical Tools-Random Variables and Probability Distributions, Data Analysis, Estimation of Statistical Tools-Random Variables and Probability Distributions, Data Analysis, Estimation of Point and Confidence Interval, Regression Analysis, Analysis of Variable Experimental Design	06	Addressing different statistical tools.
4	Quality in Design-Standardization, Tolerating-Components to Assembly.	03	Understanding of design-standardization, and tolerating aspects.
5	Quality in Processing-Process Capability, Process Planning.	03	Understanding of process capability, and planning.
6	Process Control-Statistical Process Control and Control Charts.	03	Understanding of statistical process control.
7	Sampling Plans-Scheme, Types, OC Curves.	03	Understanding of different sampling plans, and their schemes.
8	Quality in Packing-Installation and Maintenance.	03	Introducing quality aspects in packing, installation and maintenance.
9	Quality Loss Functions; Noise Factors and Analysis; Concepts of Robust Design.	04	Introducing quality loss functions.
10	Design of Experiments-Factors and Analysis,	05	Addressing design of

	One and Two Way Layouts, Latin Square, Orthogonal Array Designs, Optimal Design, Taguchi Methods.		experiments, Taguchi method.
11	Reliability-Measurement, Analysis, Allocation and Improvement.	03	Addressing reliability aspects.
12	Industry 4.0:Introduction, Evolution of Industry from 1.0 to 4.0, IoT, Nine Pillars of Technological Advancement, Smart Manufacturing Use Cases, Benefits of Adopting an Industry 4.0 Model	03	Understanding of Industry 4.0, IoT, and smart manufacturing.
	Total	**42**	

Course Outcome	At the end of the course, students should be able to 1. Understand quality concepts, scopes and analysis procedures. 2. Understand cause-effect relationship, Ishikawa diagram, design-standardization, and tolerating aspects. The students will be able to employ different statistical tools in need. 3. Analyse quality loss functions and employ design of experiments techniques. 4. Understand Industry 4.0 together with IoT and smart manufacturing features.

Learning Resources	**Text Books:** 1. Juran J.M and Frank MGryna “Quality Planning and analysis”, Tata Mc Graw Hill,1990. 2. Genichi Taguchi et all., “Quality Engineering in Production System”, Mc Graw Hill, 1989. 3. Gabriel A Pall,, “Quality Process Management”, Prentice Hall,1987. 4. D H Besterfiled "Total Quality Management" Pearson Education, 2014

Course Code	ME5145N	Course Name	Mechanical Testing and Characterization	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*1) Basic Strength of Materials, 2) Machine Design, 3)Basic Metallurgy, 4)Preliminary Knowledge of FEM*	Co-requisite Courses	*Solid Mechanics (AE&AM) (2nd Semester, Engineering Materials & Processes (4th Sem)*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			**Data Book / Codes/Standards**	*Nil*

Course Objective	To impart knowledge on the following topics: 1. ***Define*** the commonly used material characterization techniques, fundamentals of crystallography and lattice strictures, used in different day-to-day life in different industrial applications. 2. ***Classify*** the difference between destructive and non-destructive testing. 3. To understand the ***use*** of different spectroscopy and diffraction techniques, surface roughness profilometers results etc. 4. ***Conclude*** the scope of various, metallographic inspection,

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Introduction, Material Modification with Metal Working (Forging, Rolling, Casting, Welding, Solidification etc.), Theories of elasticity and plasticity	08	***Define*** the basics of metal working techniques. (CO1)
2	Fundamental of crystallography, Lattice Structures, Lattice Defects, Slip, Stacking Faults, Strain Hardening	07	***Describe*** the concepts of crystallography.(CO2)
3	Impact testing, Notched bar Impact Testing, Hardness test, Rockwell, Vickers hardness, Indenter and indentation profile, Hardness at elevated temperatures, Nano-indentation, Residual stresses, Measurement techniques, Tensile test, True stress, true strain, High and low temperature tensile test, Notch tensile test, Anisotropy of tensile properties, Torsion, Torsional stress, Torsional failure, tensile, Fatigue analysis, *S-N* Curve, Low and High cycle fatigue, Stress concentration on fatigue, Temperature-induced fatigue, Cumulative fatigue damage, Creep, Mechanism of creep, Combined Stress-induced Creep, Fracture, Theories of brittle and ductile fracture, Fractography and its Metallographic aspect, Crack formation and propagation, Stress intensity factor, Strain energy	12	***Illustrate*** the different destructive techniques of material testing.(CO3) ***Examine*** the defects identified by these techniques.(CO4)
4	Material Characterization: Optical microscopy (*OM*), Scanning Electron Microscopy (*SEM*), Energy Dispersive Spectroscopy (*EDS*), Electron Back Scattered Diffraction (*EBSD*), Transmission Electron Microscopy (*TEM*), Atomic Force Microscopy (*AFM*), X-Ray Diffraction (*XRD*), Neutron	12	***Compare*** the different non-destructive techniques of material testing. (CO2) ***Analyze*** the working principle of these

	Diffraction, Drill-hole techniques, Strain gauges, X-ray fluorescence (*XRF*), Optical emission spectroscopy *(OES)*, Laser Induced Breakdown Spectroscopy (*LIBS*), Raman Spectroscopy, Non-contact surface profile, Ultrasonic Testing (*UST*), X-Ray Computed Tomography (*XCT*), Grain structure, Phase analysis, Sample Preparation (Mounting, Polishing, Etching), Surface Roughness Measurement		techniques.(CO4)
Total		**39**	

Course Outcome	After the course, the students will have knowledge to:- 1. ***Define*** the commonly used material characterization techniques, fundamentals of crystallography and lattice strictures, used in different day-to-day life in different industrial applications. 2. ***Classify*** the difference between destructive and non-destructive testing. 3. Understand the ***use*** of different spectroscopy and diffraction techniques, surface roughness profilometers results etc. 4. ***Conclude*** the scope of various, metallographic inspection,

Learning Resources	**Text book** 1. George Ellwood Dieter - Mechanical Metallurgy (1988). **Reference book** 1. Elements of X-ray Diffraction by B. D. Cullity 2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by:Yang Leng 3. Electron Microscopy and Analysis by: P. J. Goodhew, J. Homphreys and R. Beanland 4. Microstructural Characterization of Materials by: D. G. Brandon and D. W. Kaplan 5. Characterization of Materials by: E. N. Kaufmann

Course Code	ME5211N	Course Name	Computerized Manufacturing	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	In today's world, computerized manufacturing is fast replacing the old conventional manufacturing systems, so the importance of the course is obvious. From the course, students will learn in details about CNC technology: its components, programming features, time and cost saving strategies. Emphasis is given to material handling, and high speed machining aspects.

Module	Syllabus	Duration (class-hour)	Module Outcome
CNC machines basics	Introduction to Numerical control of machine tools: Types of CNC machines, Main components of CNC machines. Feedback mechanisms	06	Understanding of different components of CNC machines, and their feedback mechanisms.
CNC machine programming	Types of CNC programs: basic terminology, Axis system: 3, 5 and 9 axes milling; Machine zero and Job zero point, G&M coding for CNC Lathe and CNC Milling.	06	Imparting knowledge about different typed CNC programs, zero concept, and G & M-codes.
CAD to CAM	Automated CNC code generation (without manual programming). Application with CNC Milling and Wire EDM	05	Implementation of the transformation from CAD to CAM, and generation of codes for milling and EDM machines.
Strategy for productivity enhancement	Canned cycle programming and Macro-programming for time-saving; Speed and feed control for precision machining; Adaptive control strategies for CNC machining.	06	Implementation of programming techniques for productivity and precision machining along with adaptive control strategies.
Material handling for computerized manufacturing	Types: Industrial Robots (basics only); Palletizing station; Conveyors, AS/RS; AGV; Automated part inspection.	04	Understanding different material handling instruments including industrial robots.
Tools for CNC machines	Types of CNC cutting tools to make quality precision parts: Drill Bits; Thread cutting tool setting; End Mill; Face Mill; Reamers; Gear Cutters; Thread Mill. CNC Turning-advanced: Tool setting methods; Work-piece setting methods and programming by using multiple tools; Tool holding system CNC machines : ATC, Tool magazine	05	Address tools used in different CNC machines together with tool setting and tool holding methods.

Economics of CNC machining	CNC Machining costs: Strategies for cost-saving and time-saving; Calculation of CNC machining costs; Sustainable CNC machining operations.	05	Addressing economical aspects of CNC machining.
High Speed Machining (HSM)	Definition of HSM, applications, advantages and limitations, Machine features and control for HSM, Tools and tool holder	03	Understanding of high speed machining concepts and control mechanisms.
	Total:	**40**	

Course Outcome	From this course, the students will be able to write programs for CNC machining for the components having simple to complex geometries, which are mostly used in industries. They will gain detailed knowledge on the components of the CNC machines, the control of the CNC system, and the feedback mechanisms for the position and speed control. Further, they will learn the time and cost saving strategies for improving the productivity.

Learning Resources	**Text books: (to change)** 1. Computer-Aided Manufacturing (Second edition) – TIEN-CHIEN CHANG, RICHARD A. WYSK, HSU-PIN WANG: Prentice Hall International Inc. 2. Machining and Machine Tools – A. B. Chattopadyay, Wiley India Pvt. Ltd., New Delhi. 3. Computer Control of Manufacturing Systems : Y Koren : McGraw Hill Education (India) Pvt Ltd, New Delhi **Reference Book:** 1. CNC Machining Handbook: Building, Programming and Implementation - Alan Overby; McGraw Hill Pub. 2. High Speed Machining - Kapil Gupta, J. Paulo Davim: Elsevier Pub., 3. Metal Cutting Principles – M.C. Shaw, Oxford University Press, Indian Addition, Kolkata**.**

Course Code	ME5212N	Course Name	Additive Manufacturing Technology	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	To impart knowledge about fundamental of additive manufacturing technologies, steps in additive manufacturing, process methodology, process parameters and control of various metal and non-metal additive manufacturing technologies.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	**Introduction to Additive Manufacturing:** Introduction to AM, AM evolution, Distinction between AM & conventional machining, Steps in AM, Classification of AM processes, Advantages of AM and Types of materials for AM	06	Impart knowledge about advantages of additive manufacturing technologies
2.	**CAD for Additive Manufacturing:** CAD Data formats, Data translation, Data loss, STL format, STL conversion error, errors checking and correction algorithm, Slicing algorithms:-uniform flat layer slicing, adaptive slicing, Process-path generation: Process-path algorithms, rasterization, part Orientation and support generation.	06	Impart knowledge about preprocessing steps in additive manufacturing
3.	**Vat Photo polymerization AM Processes:** Stereo lithography (SLA), Materials, Process Modelling, SLA resin curing process, SL scan patterns, Micro-stereo lithography, Mask Projection Processes, Two-Photon vat photo polymerization, Process Benefits and Drawbacks, Applications of Vat Photo polymerization, Material Jetting and Binder Jetting AM Processes.	04	Develop knowledge about photo polymerization type process
4.	**Extrusion - Based AM Processes:** Fused Deposition Modelling (FDM),Principles, Materials, Process Modelling, Plotting and path control, Bio Extrusion, Contour Crafting, Process Benefits and Drawbacks, Applications of Extrusion-Based Processes.	04	Develop knowledge about extrusion based process
5.	**Sheet Lamination AM Processes:** Bonding Mechanisms, Materials, Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), Gluing, Thermal bonding, LOM and UC applications.	04	Develop knowledge about sheet lamination type process
6.	**Powder Bed Fusion AM Processes:** Selective laser Sintering (SLS), Materials, Powder fusion mechanism and powder handling, Process Modelling, SLS Metal and ceramic part creation, Electron Beam melting (EBM), Process Benefits and Drawbacks,	06	Develop knowledge about powder bed fusion type process

	Applications of Powder Bed Fusion Processes, Selective Laser Melting (SLM)		
7.	**Directed Energy Deposition AM Processes:** Process Description, Material Delivery, Laser Engineered Net Shaping (LENS), Direct Metal Deposition (DMD), Electron Beam Based Metal Deposition, Processing-structure properties, relationships, Benefits and drawbacks, Applications of Directed Energy Deposition Processes. Materials science for AM – Multifunctional and graded materials in AM, Role of solidification rate, Evolution of non-equilibrium structure, microstructural studies, Structure property relationship.	06	Develop knowledge about DED type process
8.	**Post Processing of AM Parts:** Support Material Removal, Surface Texture Improvement, Accuracy Improvement, Aesthetic Improvement, Preparation for use as a Pattern, Property Enhancements using Non-thermal and Thermal Techniques .Guidelines for Process Selection: Introduction, Selection Methods for a Part, Challenges of Selection, Example System for Preliminary Selection, Process Planning and Control, AM part testing & characterization	05	Impart knowledge about various post processing techniques
	Total	**41**	

Course Outcome	Students will develop knowledge about the necessity, preprocessing and post processing process of additive manufacturing, fundamentals of various additive manufacturing technologies along with process control and input materials.

Learning Resources	**Text Books:** 1. Ian Gibson, David W Rosen, Brent Stucker., "Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing", 2nd Edition, Springer, 2015. 2. Patri K. Venuvinod and Weiyin Ma, "Rapid Prototyping: Laser-based and Other Technologies", Springer, 2004 **Reference Books:** 1. Chua Chee Kai, Leong Kah Fai, "3D Printing and Additive Manufacturing: Principles & Applications", 4th Edition, World Scientific, 2015. 2. D.T. Pham, S.S. Dimov, Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer 2001. 3. Rafiq Noorani, Rapid Prototyping: Principles and Applications in Manufacturing, John Wiley & Sons, 2006.

Course Code	ME5213N	Course Name	Micro & Nano Manufacturing	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	1.Non-Destructive Testing of Materials (ME5112) 2. Advanced Material Processing Technology (ME5113) 3. Advanced Machining Technology (ME5246)	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	**Data Book / Codes/Standards**	*Nil*		

Course Objective	To impart knowledge on the following topics: 1. ***Describe*** the concept of micromachining and nanotechnology, MEMS, Nanomaterials and their applications. 2. ***Compare*** the different fabrication processes and their mechanisms. 3. ***Use*** of different micromachining and micro-finishing processes, micro-fluidic devices etc. 4. ***Correlate*** the micro-machining aspects to biological systems.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Introduction to micromachining and nanotechnology, their differences, history of their development, application of miniaturized components in electronics, mechanical, MEMS, medical applications such as laparoscopic surgery, laser angioplasty, etc.	06	***Define*** micromachining, its pros and cons, general applications etc. (CO1)
2.	Different fabrication processes: Silicon process, LIGA process, Precision Machining Processes- Laser-Assisted Etching, Photoforming, Stereolithography, Electrochemical Micromachining, etc.	06	***Compare*** the working and performance of different fabrication process (CO2)
3.	Components of Micromachines: Microsensors, Microfittings, Microactuators-electromagnetic, electrostatic, piezoelectric, and thermally and photothermally actuated micromechanisms, Microfluidic devices.	06	***Illustrate*** the different components of different sensors and devices (CO3)
4.	Microdrip fabrication, Micromanufacturing using electron microscopes, Handling of micro components with laser tweezers, etc., Microfinishing Processes like honing, lapping, superfinishing, burnishing.	06	***Illustrate*** the different components of different sensors and devices (CO3)
5.	Mesoscopic domain of micromachines- Introduction, biological systems, cells as machines, role of proteins, physics of micromechanism, future prospects.	05	***Extend*** the scope of micro-machines in the biological domain (CO3)
6.	Fabrication of devices with high-precision nano-features on metals and semiconductors utilizing Electrochemical Microsystem Technology (EMST) and Electrochemical Nanotechnology (ENT), Self-Assembled Monolayers by molecular self-assembly, Manipulation with DNA in	06	***Categorise*** a few popular nanofabrication process (CO4)

	biological system based nanofabrication.		
7.	Nanomaterials, such as carbon nanotube (CNT) or graphene, etc. Their uses in various manufacturing applications.	06	***Outline*** the scope of using different nanomaterials (CO1)
	Total	**41**	

Course Outcome	After the completion of the course, the students will be able to: 1. ***Describe*** the fundamental concepts of micromachining and nanotechnology, MEMS, Nanomaterials and their applications. 2. ***Classify*** the available fabrication processes and their mechanisms. 3. ***Use*** of different micromachining and micro-finishing processes, micro-fluidic devices etc. 4. ***Categorize*** the different micro-machining attributes to biological systems.

Learning Resources	**Text Books:** 1. Fujimasa, Micromachines: A New Era in Mechanical Engineering, Oxford Science Publications, 1996. 2. V.K. Jain, Introduction to Micromachining, Alpha Science International Ltd., 2014. 3. J.P. Davim and M.J. Jackson, Nano and Micromachining, Wiley, 2010 **Reference Books:** 1. J.A. McGeough, Micromachining of Engineering Materials, Taylor & Francis Inc, 2001. 2. B. Bhattacharyya, Electrochemical Micromachining for Nanofabrication, MEMS andNanotechnology, Elsevier Publication, 2015. 3. S. Kalpakjian, Manufacturing Engineering and Technology, Pearson, 2002. 4. P.C. Pandey and H.S. Shan, Modern Machining Processes, Tata-McGraw Hill Publication. 5. H.E. Hofy, Advanced Machining Processes- Nontraditional and Hybrid Machining Processes, McGraw Hill Publication, New York, 2005. 6. R.L. Murty, Precision Engineering in Manufacturing, New Age International Publishers, 1996. 7. M. Ratner and D. Ratner, Nanotechnology, Prentice Hall/ Pearson Education, USA, 2003.

Course Code	ME5241N	Course Name	Quantitative Techniques in Production Management	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding on operations research, project management, linear and nonlinear programming, and design of experiments techniques along with multi-objective optimization approaches. Emphasis is given to Taguchi design of experiments technique, ANOVA, Monte-Carlo simulation, and multi-attribute utility theories.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Historical overview of operations research, fundamentals of OR Modelling, Overview of Project Management, Network analysis for time management (CPM, PERT, Crashing and Simulation)	06	Understanding of operations research, and network analysis for time management.
2	Project Resource Management: Allocation, Levelling, Smoothing methods.	04	Understanding of different stages in project resource management.
3	Linear Programming: Basic assumption, formulation, graphical methods, Simplex methods, duality theory, primal-dual relationships, sensitivity analysis. Transportation and Assignment Problems: Specific features of transportation problems, Hungarian method for solving assignment problems.	07	Address a variety of linear programming techniques.
4	Nonlinear programming, Sequential Linear Programming, Indirect method, Interior and exterior penalty Function, Karush-Kuhn Tucker conditions, Applications.	04	Address a variety of nonlinear programming techniques.
5	Design of experiments, Introduction to Factorial Designs, Regression models, Response Surface Methodology, Random effect models, Nested and Split Plot Designs, Transformations, Unbalanced ANOVA and ANCOVA, Taguchi optimization technique, applications.	06	Understanding of design of experiments techniques, their significances, utility aspects, and ANOVA
6	Introduction of robust design, Monte-Carlo Sampling, Design under uncertainty, Reliability analysis, Taguchi methods.	06	Understanding concepts of robust design, Monte-Carlo sampling, Taguchi, and reliability analyses.
7	Multi-objective optimization, Grey relation analysis, principal component analysis, Weight sum optimization, Weak and strong dominance, Pareto front computation, Goal	07	Address multi-objective optimization

	programming and iso-performance, Multi-attribute Utility Theory.		techniques, goal programming, and multi-attribute utility theories.
	Total	**40**	

Course Outcome	At the end of the course, students should be able to 1. Understand operations research, and perform network analysis for time management. 2. Perceive theory of project resource management. 3. Employ a variety of linear and nonlinear programming technique when necessary. 4. Apply design of experiments techniques with ANOVA. 5. Understand concepts of robust design, Monte-Carlo sampling, Taguchi technique, and perform reliability analyses. 6. Implement multi-objective optimization techniques, goal programming, and multi-attribute utility theories in industries.

Learning Resources	**Text Books:** 1. Gupta, P. K., Hira D. S., "Operation Research", S. Chand and Company 2. Rao, S. S., "Engineering Optimization (Theory and Practice)", John Wiley & Sons, 3. Taha, H. A. , "Operations Research", Prentice Hall of India, New Delhi, 9th Edition

Course Code	ME5242N	Course Name	Operations Management	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding of operations management and processes together with quality aspects, and facility planning. A variety of planning and scheduling techniques and material management procedures are addressed. Emphasis is given on supply chain management, TQM, CPM, PERT, and queuing model.

Module	Syllabus	Duration (class-hour)	Module Outcome
Introduction to Operational Management and Processes	Introduction to Management perspective and control approach to management, Basic management functions and managerial skills, Trends in operation management: growth, productivity changes, global competitions Operations Strategy, corporate strategy, market analysis, Process and Technologies, HR in Operations Management, Concept of productivity and its analysis, Quality aspects in Production and Services	03	Impart knowledge on the process and strategies of operations management, productivity, and quality aspects in production and related services.
Facility planning	Product and process selection, process design, process reengineering and improvement, Facilities locations: Factors influencing selection of locations, Quantitative analysis in facility location: Weight method, Weight cum rating method, Composite measure method, Locational break-even analysis, Median model, Gravity model, Bridgeman's Dimensional analysis. Plant layout: Product layout, Process Layout, G.T based layout Decision theory: under certainty, under uncertainty and under risk	04	Learn about facility planning, different quantitative analyses, and decision theory.
Production planning and control	Different types of production systems: Mass, Batch, Job, Project and continuous.	02	Address concepts of different production systems and control activities.
Forecasting	Need and importance of Forecasting, Forecasting Techniques: Delphi Method, Simple and Moving average, Exponential Smoothing, Correlation and Regression Analysis, Karl Pearson's Correlation, MAD, Tracking Signal. Numerical problems	05 02	Address forecasting techniques and associated numerical problems.
Planning & Scheduling	Different types of Planning: Long-term, Aggregate, short-term, Master Production Schedule, Rough cut capacity planning, Detail scheduling, Machine loading and sequencing: Johnson's rule and GANTT chart,	06	Understanding of planning and scheduling procedures, master production

	Assembly line balancing: Line efficiency, balance delay, smoothing index, Different techniques of balancing,		schedule including assembly line balancing.
Materials Management	Concept of inventory and its importance, Types of inventory, Saw – Tooth model, Computation of EOQ: Deterministic and Probabilistic models, Selective inventories. MRP –I and MRP – II, JIT	05	Address material management concepts, EOQ model, and MRP modules.
Supply Chains	Evolution of Supply chain and its definition, Push pull view of supply chain, Cycle View of supply chain, Supply chain drivers, Factors affecting the supply chain performance, Efficient supply chain and responsive supply chain and its strategic fit, Bullwhip effect of supply chain, Merits and demerits of supply chain.	03	Understanding of supply chain procedures.
Project Management	Management of technology: creation, acquisition, integration, economic justification. Concept of project and network analysis and network diagram, Work-force management. TQM, Computation of project completion time (Forward pass and backward pass), CPM, Computation of float, Difference between PERT and CPM, Probabilistic time estimates, probability of project completion by a target date, Project crushing. Numerical Problems	04	Address project management theories including network analysis, TQM, PERT, CPM, and related numerical problems.
Queuing Model	Waiting line problem and its application, Characteristic of the Queue and the service facilities, Poisson arrival and Exponential service distribution, Traffic intensity, Computation of Waiting time, number of customers in the system, decision problems in queuing.	04	Address queuing model and discuss its significance in manufacturing industries.
	Total Classes	**42**	

Course Outcome	At the end of the course, students should be able to 1. Understand the process and strategies of operations management, productivity, and quality aspects in production and related services. 2. Learn about facility planning, different quantitative analyses, and decision theory. 3. Understand concepts of different production systems and control activities. 4. Perceive forecasting techniques and implement them. 5. Understand planning and scheduling procedures, master production schedule including assembly line balancing. 6. Comprehend material management concepts, EOQ model, and MRP modules. 7. Perceive supply chain procedures. 8. Implement management theories including network analysis, and TQM, PERT, CPM concepts. 9. Understand queuing model and its significance in manufacturing industries.

Learning Resources	**Text Books:** 1. Essentials of Management by Koontz &Weihrich, TMH. 2. Taha, H. A. , "Operations Research", Prentice Hall of India, New Delhi, 9th Edition 3. Modern Production / Operations Management by E.S. Buffa and R.K. Sarin, John Wiley & Sons. 4. Quantitative techniques in Management by N. D. Vohra, Tata McGraw Hill. 5. Production Planning and Inventory Control by Narasimhan, McLeavey, Billington, PHI. 6. Logistic and supply chain management by Martin Chirstopher, Pearson Education. 7. Levin R.I. and Rubin D.S., "Statistics for management", Prentice Hall of India Pvt. Ltd., New

	Delhi, **Reference Books:** 1. Production and Operation Management by Muhlemann, Oakland and Lockyer, Mcmillian India Ltd. 2. An Introduction to Management science by Anderson, Sweeny and Williams, Thomson South west. 3. Supply Chain Management by Chopra and Meindl, Pearson Education, 3rd Ed., 2007 4. Gupta, P. K., Hira D. S., "Operation Research", S. Chand and Company.

Course Code	ME5243N	Course Name	Advanced Material Management	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding of the material management, supply chain, material planning, enterprise resource planning, and inventory management. Concepts like forecasting, lean management and TQM are addressed. Emphasis is given to six sigma, ISO 9000 certifications, and process control.

Module	Syllabus	Duration (class-hour)	Module Outcome
I. Introduction	Introduction to materials management, operating environment, supply chain concept, role of material management	02	Understand the concepts of material management and supply chain.
II. Material Planning	Material Planning-definition Material Requirements Planning (MRP) – definition, influencing factors, objectives of MRP, Linkages to Other Manufacturing Planning and Control (MPC) Functions, bills of material, material requirements planning process – exploding and offsetting, gross and net requirements, releasing orders, capacity requirements planning, low-level coding and netting, multiple bills of material. Manufacturing resource planning (MRPII), enterprise resource planning (ERP), Capacity requirements planning (CRP), Distribution Requirements Planning (DRP) Cases studies.	08	Conceptualize MRP, and understand the link between MRP and MPC functions. Understand the utility aspects of ERP, CRP, and DRP.
III. Purchasing	Importance and objectives of good purchasing system, Purchasing Cycle, Make or Buy decisions, establishing specifications, selecting suppliers, price determination, impact of MRP on purchasing, Incoming Material Quality Assurance, Value analysis for material cost reduction.	06	Gain knowledge of purchasing procedures, supplier selection, price determination, and quality assurance of incoming items.
IV. Forecasting	Forecasting-definition & purpose, factors influence demand, demand forecasting, principles of forecasting, data collection forecasting techniques- classification, study of Average demand, Moving Averages, Exponential Smoothing. Seasonality, seasonal forecasts, deseasonalized demand. Tracking the forecast. Cases studies.	06	Conceptualize forecasting and associated techniques for its evaluation.
V. Inventory management	Inventory vs stores, functions and types of inventory, types of inventory control, handling uncertainties and safety stock, inventory build-up, EOQ for various inventory models, inventory models with quantity	08	Gain knowledge about inventory management, different inventory

	discount, exchange curve concept, coverage analysis, optimal stocking policies, inventory management of perishable commodities, ABC-VED analysis, design of inventory distribution systems, spare parts inventory management, information systems for inventory management, cases studies.		models, EOQ, and related analyses.
VI. JIT and Lean Production	Just-In-Time philosophy, causes of waste, JIT environment, manufacturing planning and control in a JIT environment, lean production, which to choose—MRP (ERP), Kanban, or theory of constraints?	05	Learn about Lean production, JIT philosophy in industry applications.
VII. Total quality management	What is quality? Definition and purpose of TQM, six basic concepts of TQM, quality cost concepts, process capability, process control, reasons and conditions of sample inspection, ISO 9000:2000 documentation, benchmarking and six sigma.	07	Understand about TQM, six sigma, and ISO 9000 certifications.
	Total Classes	**42**	

Course Outcome	At the end of the course, students should be able to 1. Perceive the concepts of material management and supply chain. 2. Learn about MRP, and understand the link between MRP and MPC functions. 3. Understand ERP, CRP, and DRP concepts. 4. Gain knowledge about purchasing procedures, supplier selection, price determination, and quality implications on incoming items. 5. Implement forecasting techniques. 6. Understand about inventory management, different inventory models, EOQ, and related analyses. 7. Implement Lean, and JIT philosophies in industry applications. 8. Learn about TQM, six sigma, and ISO 9000 certifications.

Learning Resources	**Text Books:** 1. J. R. Tony Arnold, Stephen N. Chapman, & Lloyd M. Clive, **"Introduction to Materials Management"**, Prentice Hall 2. P. Gopalakrishnan, **"Purchasing and Materials Management"**, Tata McGraw Hill 3. P Gopalkrishnan& M. Sudarshan,**"Materials Management"**, PHI learning pvt ltd **Reference Books:** 1. W. R. Stelzer, **"Materials Management"**, PHI learning pvt ltd 2. Donald Waters, **"Inventory Control and Management"**, John Wiley & Sons 3. Ed C. Mercado, **"Hands-on Inventory Management (Series on Resource Management)"**, Auerbach Publications

Course Code	ME5244N	Course Name	Material Handling	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	*Nil*

Course Objective	To impart knowledge on the following topics: 1. ***Define*** the conventional as well as modern material handling (MH) systems, common automated handling arrangements, storage systems etc. and thereby choose the different available tools and techniques of MH, etc. used in different day-to-day life in different industrial applications. 2. ***Illustrate*** the basic designing principles and working mechanisms of MH systems. 3. To ***solve*** the numerical to determine the quantity, acting forces etc. associated with MH system. 4. Mathematical formulations, optimization and ***modeling*** to ***analyze*** the safety load, forces acting, safe capacity of different MH system.

Module	Syllabus	Duration (class-hour)	Module Outcome
I.	**Introduction:** Introduction to material handling concepts in manufacturing – configuration, symbolic representation, work piece characteristics and their significance, Facilities planning process, Facilities design and diagrams, Storage facilities planning, Materials flow, Activity relationship, Space requirements, Facility lay out – computerized lay outs, Evaluation and selection of alternatives, Defined materials handling, Storage – open and closed storage systems, Bulk loading, Unloading, Shipping and Receiving systems and operations.	08	***Define*** the basics of the material handling system (CO1). ***Classify*** the different types of storage facilities (CO2).
II.	**Materials Handling Equipment:** Concepts of Unit Loads, Material handling and Storage equipment operation and selection, Containers, Pallets, Conveyor systems, Industrial trucks, Wagon tipplers, Transporters, Stackers, Reclaimers, Silos & hoppers and their accessories, Ropeways, Ship loaders, Cable cranes, Container handling systems, Electric lifts & Hoists, EOT cranes, Elevators, Material handling equipment in Steel mills, Power plants, Mines, Automobile and Transport Industries, Large scale Constructions etc.	09	***Describe*** the difference between unit, bulk and unitized loading (CO1) ***Discuss*** the equipment needed for the material handling system (CO2). ***Show*** the different types of hoisting equipment (CO3). ***Examine*** problems on FLT, belt and screw conveyor etc. (CO4).
III.	**Automation of Material Handling:** Automated feeding arrangements for discrete parts, their design based in work piece requirements, orienting methods, one by one feeding, agonizing, stapling etc., - Feeding continuous material liquids, granules etc., - Automated assembly system, elements, configuration design, details and control – Special	08	***Describe*** the role of automation in the material handling system. (CO1) ***Lists*** the feeding

	feeding mechanisms – Automated inspection and their design		mechanisms in the pneumatic conveyors. (CO1)
IV.	**Classification of Automated Systems:** Concepts of Unit Built Machines (UBM) – classification and elements, Power Units, self-contained and separate feed type, Change over UBMs, Transfer lines – classification and their components, Automated systems for handling and transfer of prismatic, axis symmetric parts and asymmetric parts in transfer lines, Case studies on transfer lines – interlocked, palletized and flexible inter linkage transfer lines, control systems – SWARF handling and disposal systems.	08	***Explain*** the idea of an unit built machine and associated transfer lines. (CO2)
V.	**Automated Material Handling Equipments:** Automated handling and storage systems in manufacturing environment, Rail Guided Vehicles (RGVs), Automated Guided Vehicles (AGVs), Applications of RGVs and AGVs, Automated Storage and Retrieval Systems (AS / RS), AS / RS in the Automated factory, Considerations for planning an AS /RS system, Applications of AS / RS, Principles of work holding devices – Modular fixturing, Flexible fixturing systems – Fixturing for FMS, Robots and their applications in handling and storage.	09	***Outline*** the different automated devices, robotic gadgets used for material handling (CO1) ***Recognize*** the use of sensors and robotic systems in industries for material handling. (CO1)
	Total	**42**	

Course Outcome	After the completion of the course, the students will be able to: 1. ***Define*** the fundamental concepts of material handling (MH) and choose desired MH technique as per requirements. 2. ***Explain*** the designing principles and working mechanisms of MH systems. 3. ***Solve*** numerical associated with different MH system. 4. Formulate, and ***analyze*** the load carrying capacity, safety etc. associated with the MH system.

Learning Resources	**Text book** 1. Groover, M.P., Automation, Production Systems and CIM, prentice hall India, 2007. 2. Morris, A. C., Uday, M.A., Manufacturing Automation, Irwin, Chicago, 1997. 3. Asfahl, C. R., Robots and Manufacturing Automation, 2nd edition, John Wiley & Sons, New York, 1992. 4. James, M.A., 'Principles of layout and material handling', Ronald press, 1977. 5. Apple, J.M., Material Handling System Design, John Wiley & Sons **Reference book** 1. Allegri, T.H., Materials Handling: Principles and Practice, CBS Publishers & Distributors, N. Delhi 2. Alexandrov, M.P., Materials Handling Equipment, Part-I and II, Mir Publishers, Moscow 3. Ray, T.K., Mechanical Handling of Materials, Asian Books Private Ltd., 2004 4. Ray, S., Introduction to Materials Handling, New Age International Publishers, 2008.

Course Code	ME5245N	Course Name	Maintenance and Reliability	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	The goal of the course is to provide students a comprehensive understanding of the maintenance planning, principle, and activities together with reliability aspects. Condition monitoring along with failure models, reliability design process and procedure are addressed. Emphasis is given to material selection, strength analysis, failure models, and system safety index.

Module	Syllabus	Duration (class-hour)	Module Outcome
Principles and practices of maintenance planning	Basic Principles of maintenance planning – Objectives and principles of planned maintenance activity – Importance and benefits of sound Maintenance systems – Reliability and machine availability – MTBF, MTTR and MWT – Factors of availability – Maintenance organization – Maintenance economics.	08	Understand basic concepts of maintenance planning, and concepts of reliability.
Maintenance policies – preventive maintenance	Maintenance categories – Comparative merits of each category – Preventive maintenance, maintenance schedules, repair cycle – Principles and methods of lubrication – TPM.	07	Understand different categories of maintenance, and its schedule.
Condition monitoring	Condition Monitoring – Cost comparison with and without CM – On-load testing and offload testing – Methods and instruments for CM – Temperature sensitive tapes – Pistol thermometers – wear-debris analysis	09	Impart knowledge on condition monitoring, methods, and analyses.
Concepts of reliability, system and models	Definition of reliability – reliability Vs quality-reliability function-MTTF – hazard rate function- bathtub curve – derivation of the reliability function-constant failure rate model – time dependent failure models. Weibull distribution – normal distribution – the lognormal distribution. Serial configuration – parallel configuration – combined series parallel systems – system structure function, minimal cuts and minimal paths – Markov analysis – load sharing systems, standby system, degraded systems, three state devices – covariate models, static models, dynamic models, physics of failure models.	08	Address reliability, different analytical tools for evaluating reliability, and existing models.
Design for reliability and maintainability	Reliability design process – system effectiveness – economic analysis and life cycle cost – reliability allocation – optimal, Arinc, Agree, – Design methods – parts and material selection, derating, stress- strength analysis – failure analysis – identification of failure mode – determination of causes –assessment of effects – classification of seventy – computation of critically index –	08	Address design processes of reliability, and failure analysis. Impart knowledge on system safety, and preventive and

	corrective action – system safety and FTA. Analysis of downtime – the repair time distribution – stochastic point processes – system repair time – reliability under preventive maintenance – state dependent systems with repair – MTTR-mean system downtime – MTR – MH/OH – cost model – fault isolation and self-diagnostics – repair Vs replacement – replacement model – proactive, preventive, predictive maintenance – maintenance and spares provisioning – maintainability prediction and demonstration – concepts and definition of availability.		predictive maintenance schedules.
	Total	**40**	

Course Outcome	At the end of the course, students should be able to 1. Understand basic aspects of maintenance planning and concepts of reliability. 2. Understand different categories of maintenance, and its schedule. 3. Impart knowledge on condition monitoring, methods, and its analyses. 4. Conceptualize reliability, different analytical tools for evaluating reliability, and imply existing models. 5. Understand design process of reliability, and perform failure analysis. 6. Develop knowledge on system safety, preventive and predictive maintenance schedules.

Learning Resources	**Text Books:** 1. Srivastava S.K., "Industrial Maintenance Management", S. Chand and Co., 1981 2. Venkataraman. K "Maintenance Engineering and Management", PHI Learning, Pvt. Ltd., 2007 3. Charles E. Ebling, "An introduction to Reliability and Maintainability Engg", Tata McGraw-Hill, 2000

Course Code	ME5246N	Course Name	Advanced Machining Technology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	1. Advanced Material Processing Technology (ME5113) *2.* Non-Traditional Machining (ME5112)	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	**Data Book / Codes/Standards**		*Nil*	

Course Objective	To impart knowledge on the following topics: 1. ***Describe*** the conventional as well as non-conventional machining techniques, introduction to NC and CNC and other parameters affecting the machining qualities. 2. ***Illustrate*** the role of cutting fluids, metallurgy of machining. 3. To ***calculate*** the surface roughness, cutting forces during machining operation. 4. ***Examine*** the influence of machining parameters on the surface roughness.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.Advanced tool materials	Advanced tool materials: Coated tools, High performance ceramic tools, Cryo treated tools.	04	***Define*** the basics of commonly used tools, advanced tools used for machining (CO1).
2.Determination of cutting forces	Experimental determination of cutting forces: Dynamometry, Piezo-electric dynamometer: Design and construction.	05	***Solve*** problems on force determination on tools (CO4).
3.Measurements of wear & cutting temperature	Experimental techniques for wear measurements. Modeling and measurement of cutting temperature.	05	***Explain*** the different methods of measuring wear, cutting temperature etc. (CO2).
4.Surface Integrity	Surface Integrity: Surface Metallurgy and Surface Topography, Measurement of surface roughness.	04	***Show*** the techniques to measure the surface roughness (CO3).
5.Advanced grinding	Advanced techniques of grinding and modern grinding wheels.	05	***Describe*** the working of a grinding wheels (CO2).
6.Cutting fluids	Modern application of cutting fluids: Environmental aspects, Cryogenic machining, MQL principle.	06	***Demonstrate*** the use of cutting fluids, their working, properties etc. (CO3).
7.NC & CNC	Introduction to Numerical control of machine tools: NC, CNC, DNC machines. Tool Condition monitoring, Adaptive control systems, Turning Center, Machining Center, Automatic Tool Changer, Part Programming.	08	***Discuss*** the basics of numerical control, part programming etc. (CO2).
8.Non-Traditional machining	Introduction to Non-Traditional machining: EDM, ECM, AJM, USM, LBM.	04	***Extend*** knowledge on other non-conventional manufacturing techniques (CO2).
	Total	**41**	

Course Outcome	After this course, the students will have specific knowledge/skill set: 1. ***Outline*** the traditional and non-traditional machining process, introduction to NC and CNC and other parameters affecting the machining qualities. 2. ***Express*** the use of different cutting fluids on heat dissipation, metallurgical changes on the machined surfaces. 3. To ***solve*** numerical related to estimation of surface roughness, cutting forces during machining operation. 4. ***Categorize*** the influence of machining parameters on the surface roughness.

Learning Resources	**Text book** 1. Machining and machine tools, A.B.Chattopadhyay, John Wiley & Sons 2. Manufacturing Science, A Ghosh & A.K. Mallik, Pearson India 3. Metal Cutting: Theory and Practice, Amitabha Bhattacharya, New Central Book Agency. **Reference book** 1. Nonconventional Machining, P.K. Mishra, Narosa 2. Manufacturing Engineering and Technology, S. Kalpakjian, S. R. Schmid, Pearson Education

Course Code	ME5247N	Course Name	Energy-Beam Processing of Materials	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Non-Traditional Machining	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	*Mechanical Engineering*			Data Book / Codes/Standards	Nil

Course Objectives	The course aims in • Understanding the concept of Energy-Beam Processing of materials. • Understanding the fundamentals of mechanical jet and thermal jet machining processes. • Understanding the principle, mechanism of material removal of various energy beam processes (Laser beam, Electron beam, Ion beam, Plasma). • Studying the various process parameters and their effects on the machined components. • Elucidation of the applications of different processes.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Basic concept of energy-beam processing, power density, spot size and specific processing energy of different energy-beam processes.	04	• Understanding the basics of energy-beam processing, power density, spot size and specific processing energy of different energy-beam processes.
II	Fundamentals of jet machining, comparison of mechanical jet machining processes with thermal jet machining processes.	06	• In-depth knowledge on principle, analysis and applications of mechanical jet and thermal jet machining processes.
III	Lasing process, constructional features of laser cavity, laser beam machining, welding, surface treatment and other applications of laser.	04	• Comprehensive knowledge on principle, analysis and applications of laser beam in machining, drilling, welding and surface treatment.
IV	Fundamentals of electron beam processing, equipment used, process parameters, electron beam machining, electron beam welding.	04	• Thorough knowledge on principle, analysis and applications of electron beam processes.
V	Ion beam processing, equipment used, process parameters, ion beam machining, ion beam etching.	04	• Comprehensive knowledge on principle, analysis and applications of electron beam processes.
VI	Comparison of material processing with continuous beam and pulsed beam, effect of pulse duration, selection of pulse parameters for different material processing operations.	04	• Understanding the basics of material processing with continuous beam and pulsed beam, effect of pulse duration, selection of pulse parameters for different material processing operations.
Total		**42**	

Course Outcome	After successful completion of the course, the student shall be able to • Understand the principle of working, mechanism of material removal in the various energy beam processes. • The student shall also be able to identify the process parameters, their effects and applications of different energy beam processes.

Learning Resources	**Text Books:** 1. Laser Material Processing by W.M. Steen, Springer-Verlag. 2. Non traditional Manufacturing by G. F. Benedict, Marcel Dekkar Inc. 3. Nonconventional Machining by P. K. Mishra, Narosa Publishing House. **Reference Books:** 1. Modern Machining Processes by P.C. Pandey and H.S. Shan, Tata McGraw Hill. 2. Manufacturing Processes for Engineering Materials by S. Kalpakjian and S.R. Schmid, HMT, Pearson Education India Ltd.

Course Code	ME5248N	Course Name	Advanced Operations Research	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department		*Mechanical Engineering*		Data Book / Codes/Standards	*Nil*

Course Objective	To impart knowledge on the following topics: 1. ***Define*** the basic theory on linear programming, game theory, simplex methods, transportation etc. 2. ***Describe*** the basic of dual simplex method, parametric study etc.. 3. To ***solve*** the numerical related to above stated topics. 4. ***Analyze*** the results obtained through different techniques.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Role of operation research in production management, A brief Introduction to linear programming, simplex method, Big-M method, Some special cases of LPP	07	***Describe*** the basics of linear programing, simplex methods etc. (CO1)
2.	Dual simplex method, Concept of Duality, sensitivity and parametric analysis of dual problem, post-optimal analysis, Problems on Dual Problems.	06	***Recognize*** the concept of duality, parametric analysis etc. (CO2)
3.	A brief introduction on Transportation and Assignment, Industry specific Problems on Transportation and Assignment	07	***Demonstrate*** the transportation and assignment related topics (CO3).
4.	Parametric linear programming. Network models, project scheduling by PERT-CPM.	06	***Discuss*** the concept of network model, PERT-CPM etc. (CO2)
5.	Queuing models, Game theory	06	***Demonstrate*** the basic working of game theory (CO3).
6.	Integer and non-integer linear programming, problems on Integer linear programming	04	***Solve*** *problems on* Linear programming (CO3).
7.	Dynamic programming, Sensitivity analysis, Revised Simplex method	06	***Analyze*** the concept of sensitivity analysis, dynamic programming etc. (CO4).
	Total	**42**	

Course Outcome	After the completion of the course, the students will be able to:- 1. ***Define*** the basic theory on linear programming, game theory, simplex methods, transportation etc. 2. ***Explain*** the concepts of dual simplex method, parametric study etc. 3. To ***solve*** the numerical related to above stated topics. 4. ***Analyze*** the results obtained through different techniques.

Learning Resources	**Text book** 1. Operations Research-An Introduction by Hamdy A. Taha, Prentice Hall of India Pvt Ltd **Reference book** 1. Operations Research-Principles and Practice by A Ravindran, Donald T. Phillips, and James J. Solberg. Wiley Student Edition 2. Introduction to Operation Research by Frederick S. Hillier, Gerald J. Lieberman, B. Nag and P. Basu. Tata McGraw-Hill Publication 3. Operations Research by D. S. Hira and P. K. Gupta. S Chand Publication.

Course Code	ME5249N	Course Name	Metal Forming	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	1. Advanced Material Processing Technology (ME5113) *2.* Non-Traditional Machining (ME5112)	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*		**Data Book / Codes/Standards**		*Nil*

Course Objective	To impart knowledge on the following topics: 1. ***Describe*** the basics of forging, rolling, extrusion and other forming operations, their merits, limitations and application areas. 2. ***Illustrate*** the different theories of failure, material behaviour under different forming conditions. 3. To ***calculate*** the forces associated with the different forming operations, surface roughness, punch-die numerical etc. 4. ***Point out*** the mechanism of different forming operations and study of material behaviour subjected to various forming.

Module	Syllabus	Duration (class-hour)	Module Outcome
1.	Introduction to metal forming, advantages and classifications of metal forming processes, forming properties of metals and alloys, mechanics of metal forming, effect of variables on forming process, hot working, warm working, cold working, recrystallization, grain structure, friction and lubrication in metal forming	05	***Describe*** basics of forming process, its pros, cons etc. (CO1). ***Explain*** the mechanics of forming operations, microstructural changes (CO2).
2.	Elastic and plastic deformation behaviour, stress-strain relation, theoretical analysis (fundamentals of plasticity), yield criteria, flow and deformation theories, strain hardening, material incompressibility, work of plastic deformation, instability and anisotropy, initiation and extent of plastic flow, analysis of forming processes: slab analysis, upper bound theorem, slip-line field.	10	***Recognize*** the elastic and plastic behaviour of metals (CO2). ***Examine*** the influence of forming operations on the process of strain hardening, isotropic and anisotropic behaviour, plastic properties etc. (CO3) ***Examine*** the use of forming limit diagram (CO4)
3.	Forging (classification, equipment, forging in plane-strain, deformation and defects in forging, residual stresses in forging, process details and power calculation)	05	***Recognise*** the basics of forging process, its classification, pros, cons etc. (CO1). ***Discuss*** its classification and usages etc. (CO2).
4.	Rolling (classification, equipment, variables, force, deformation and defects in rolling, theories of hot and cold rolling, process details and power calculation)	05	***Recognise*** the basics of rolling process, its classification, pros, cons etc. (CO1). ***Extend*** the knowledge of hot and cold forming, (CO2).
5.	Extrusion (classification, equipment, variables, deformation and defects in extrusion, extrusion under ideal condition, process details and power	05	***Outline*** basics of extrusion process (CO1). ***Classify*** the different sheet metal

	calculation)		operations (CO2). ***Calculate*** the forces acting on tool-die operations, spring back etc. (CO3)
6.	Sheet metal forming process (introduction, forming methods, tool and dies, bending, power estimation, spring back calculation, deep drawing, defects in formed parts, formability test, forming limit diagram)	05	***Define*** basics of sheet metal forming operations (CO1). ***Classify*** the different sheet metal operations (CO2). ***Calculate*** the forces acting on tool-die operations, spring back etc. (CO3) ***Examine*** the use of forming limit diagram (CO4)
7.	Modelling techniques for metal forming processes.	05	***Demonstrate*** the working and usages of common modelling techniques for forming operations (CO3).
	Total	**40**	

Course Outcome	After this course, the students will have specific knowledge/skill set: To impart knowledge on the following topics: 1. ***Outline*** the primary information on forging, rolling, extrusion and other forming operations, their pros, cons and usages. 2. ***Express*** the material behaviour subjected to different forming conditions using different theories of failure. 3. To ***solve*** the forces, punch-die calculations etc. associated with the different forming operations 4. ***Categorize*** the influence of different forming operations on the change in stress-strain behaviour and other material behaviour for different forming operations.

Learning Resources	**Text book** 1. Mechanical Metallurgy, GE Dieter, McGraw Hill Company. **Reference book** 1. Manufacturing Process for Engineering Materials, by S Kalpakjian& SR Schmidt, Pearson Education India, New Delhi, 2009. 2. Modelling Techniques for Metal Forming Processes by GK Lal, PM Dixit, N Venkata Reddy, Narosa Publication, 2011. 3. Principle of Industrial Metal Working Process, GW Rowe, CBS Publication, New Delhi.