Course Structure & Curriculum
for
Master of Technology in
Mechanical Engineering

Indian Institute of Engineering Science and Technology, Shibpur
Howrah – 711 103

February, 2025

Notes:

1. **Total M. Tech. Programme Credit: 21 + 21 + 18 + 30 = 90**

2. The credits mentioned above are indicative and are as such to be followed. However, in cases, where it is essential to include a Tutorial credits may be increased to 4 (Theory). In such cases, the total credit should not exceed 23.

3. Paper – IV in 1st Semester and Paper – IX in 2nd Semester are departmental elective subjects, and Paper – V in 1st Semester and Paper – X in 2nd Semester are open elective subjects respectively, which are to be selected from the table below. A student must opt for open electives offered by other departments only, subject to availability.

4. Open elective subjects, which are offered by ME department can be taken by other department students only but not by ME students. ME department students can take open electives offered by other departments.

5. For M. Tech. Thesis Part - I (Term Paper), the student will work under the guidance of the Supervisor(s) from the beginning of the second semester, and submit the Term Paper (literature review and objective and scope of the broad area of M. Tech. thesis work). Submission will be followed by a seminar and viva-voce.

6. For M. Tech. Thesis Part - II (Progress Report), the student will submit the details of work done for the M. tech Thesis during the third semester, and findings (if any). Submission will be followed by a seminar and viva-voce.

7. For M. Tech. Final thesis, the student will compile the entire work done for the M. Tech Project, along with the findings, in the form of a Thesis and submit at the end of the semester. Thesis submission will be followed by a Thesis seminar and viva-voce.

8. DCYSCC is the full code of a subject, where, DC: Department Code (AE, CE, ME, etc.), Y: Year (5, 6 for M. Tech. and 8 for Ph.D.), S: Semester Code (1 for odd semester and 2 for even semester), CC: Course Code (1-20 for Core Theory courses, 21-60 for Departmental Electives, 61-70 for Open Electives; 71-90 for Laboratory courses with weekly class loads, 91-99 for Thesis/Project/Internship/Viva etc., without weekly class loads).Paper –I, II, III in 1st Semester and VI, VII,VIII in 2nd Semester are compulsory subjects for the particular specialization, denoted as Departmental Core.

Course Structure
for
Thermal Science and Energy Technology

A. First Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	Paper – I: Dept. Core	ME-5101	Advanced Engineering Thermodynamics	3	0	0	3	100
2	Paper – II: Dept. Core	ME-5102	Solar, Wind & Biomass Energy Systems	3	0	0	3	100
3	Paper – III: Dept. Core	ME-5103	Advanced Fluid Mechanics	3	0	0	3	100
4	Paper – IV: Dept. Elective	List below	List below	3	0	0	3	100
5	Paper – V: Open Elective	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal							**15**	**500**
6	Lab - I / Mini Project - I	ME-5171	Thermal Simulation Laboratory	0	0	2	2	50
7	Lab - II / Mini Project - II	ME-5172	Renewable Energy Laboratory	0	0	2	2	50
8	Lab - III / Mini Project - III	ME-5173	CFD Laboratory	0	0	2	2	50
Practical Subtotal							**6**	**150**
First Semester Total Credit							**21**	**650**

List of Departmental/Open Electives for First Semester

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

B. Second Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	Paper – VI: Dept. Core	ME-5201	Hydrogen Energy & Fuel Cells	3	0	0	3	100
2	Paper – VII: Dept. Core	ME-5202	Advanced Energy Storage Systems	3	0	0	3	100
3	Paper – VIII: Dept. Core	ME-5203	Advanced Heat Transfer	3	0	0	3	100
4	Paper – IX: Dept. Elective	List below	List below	3	0	0	3	100
5	Paper – X: Open Elective	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal							**15**	**500**
6	M. Tech. Project Part - I	ME-5291	M. Tech. Project Part - I (Term Paper)	0	0	4	4	200
7	Seminar & Viva-voce	ME-5292	Term Paper Seminar & Viva-voce	0	0	2	2	100
Practical Subtotal							**6**	**300**
Second Semester Total Credit							**21**	**800**

List of Departmental/Open Electives for Second Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5221	Numerical Heat Transfer & Fluid Flow
Departmental Elective	ME-5222	Energy Efficient Buildings
Departmental Elective	ME-5223	Cryogenic Systems and Equipment
Departmental Elective	ME-5224	Distributed Energy Systems & Micro-grids
Departmental Elective	ME-5225	Clean Coal Technology
Departmental Elective	ME-5226	Carbon Capture & Storage
Departmental Elective	ME-5227	IC Engines & Electric Vehicles
Open Elective	NO OPEN ELECTIVES ARE OFFERED	

C. Third Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	M. Tech. Project Part - II	ME-6191	M. Tech. Project Part - II (Progress Report)	0	0	12	12	300
2	Seminar & Viva-voce	ME-6192	Progress Report Seminar & Viva-voce	0	0	6	6	100
Practical Subtotal							**18**	**400**
Third Semester Total Credit							**18**	**400**

D. Fourth Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	M. Tech. Final Thesis	ME-6291	M. Tech. Final Thesis	0	0	22	22	400
2	Seminar & Viva-voce	ME-6292	Thesis Seminar & Viva-voce	0	0	8	8	200
Practical Subtotal							**30**	**600**
Fourth Semester Total Credit							**30**	**600**

Course Structure
for
Machine Design

A. First Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	Paper – I: Dept. Core	ME-5106	Advanced Solid Mechanics[1]	3	0	0	3	100
2	Paper – II: Dept. Core	ME-5107	Linear and Non-Linear Vibration[2]	3	0	0	3	100
3	Paper – III: Dept. Core	ME-5108	Geometric Modelling for CAD[1]	3	0	0	3	100
4	Paper – IV: Dept. Elective	List below	List below	3	0	0	3	100
5	Paper – V: Open Elective	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal							**15**	**500**
6	Lab - I / Mini Project - I	ME-5176	Mini Project on Advanced Solid Mechanics	0	0	2	2	50
7	Lab - II / Mini Project - II	ME-5177	Vibration Laboratory	0	0	2	2	50
8	Lab - III / Mini Project - III	ME-5178	Geometric Modelling for CAD Laboratory	0	0	2	2	50
Practical Subtotal							**6**	**150**
First Semester Total Credit							**21**	**650**

List of Departmental/Open Electives for First Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5141	Machine Learning for Mechanical Engineers[2]
Departmental Elective	ME-5132	Engineering Tribology
Departmental Elective	ME-5133	Applied Elasticity and Plasticity
Departmental Elective	ME-5134	Advanced Mechanics of Machines
Departmental Elective	ME-5135	Design Optimization
Departmental Elective	ME-5136	Biomechanics
Open Elective	ME-5162	Industrial Robotics

B. Second Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	Paper – VI: Dept. Core	ME-5206	Fatigue, Creep and Fracture Mechanics	3	0	0	3	100
2	Paper – VII: Dept. Core	ME-5207	Control of Mechanical Systems[2]	3	0	0	3	100
3	Paper – VIII: Dept. Core	ME-5208	Computational Mechanics of Solids[2]	3	0	0	3	100
4	Paper – IX: Dept. Elective	List below	List below	3	0	0	3	100
5	Paper – X: Open Elective	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal							**15**	**500**
6	M. Tech. Project Part - I	ME-5291	M. Tech. Project Part - I (Term Paper)	0	0	4	4	200
7	Seminar & Viva-voce	ME-5292	Term Paper Seminar & Viva-voce	0	0	2	2	100

Practical Subtotal	**6**	**300**
Second Semester Total Credit	**21**	**800**

List of Departmental/Open Electives for Second Semester

Paper Category	Paper Code	Subject Name
Departmental Elective	ME-5231	Introduction to Modern Materials[2]
Departmental Elective	ME-5232	Bearing Lubrication
Departmental Elective	ME-5233	Design of Piping Systems
Departmental Elective	ME-5234	Non-Destructive Testing of Materials
Departmental Elective	ME-5235	Industrial Tribology
Departmental Elective	ME-5236	Data-Driven Dynamical Systems[2]
Open Elective	NO OPEN ELECTIVES ARE OFFERED	

C. Third Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	M. Tech. Project Part - II	ME-6191	M. Tech. Project Part - II (Progress Report)	0	0	12	12	300
2	Seminar & Viva-voce	ME-6192	Progress Report Seminar & Viva-voce	0	0	6	6	100
Practical Subtotal							**18**	**400**
Third Semester Total Credit							**18**	**400**

D. Fourth Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	M. Tech. Final Thesis	ME-6291	M. Tech. Final Thesis	0	0	22	22	400
2	Seminar & Viva-voce	ME-6292	Thesis Seminar & Viva-voce	0	0	8	8	200
Practical Subtotal							**30**	**600**
Fourth Semester Total Credit							**30**	**600**

Course Structure
for
Advanced Manufacturing Technology

A. First Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	Paper – I: Dept. Core	ME-5111	Industrial Engineering	3	0	0	3	100
2	Paper – II: Dept. Core	ME-5112	Non-Traditional Machining	3	0	0	3	100
3	Paper – III: Dept. Core	ME-5113	Advanced Material Processing Technology	3	0	0	3	100
4	Paper – IV: Dept. Elective	List below	List below	3	0	0	3	100
5	Paper – V: Open Elective	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal							**15**	**500**
6	Lab - I / Mini Project - I	ME-5181	Industrial Engineering Laboratory / Mini project	0	0	2	2	50
7	Lab - II / Mini Project - II	ME-5182	Non-Traditional Machining Laboratory	0	0	2	2	50
8	Lab - III / Mini Project - III	ME-5183	Advanced Material Processing Technology Laboratory	0	0	2	2	50
Practical Subtotal							**6**	**150**
First Semester Total Credit							**21**	**650**

List of Departmental/Open Electives for First Semester

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

B. Second Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	Paper – VI: Dept. Core	ME-5211	Computerized Manufacturing	3	0	0	3	100
2	Paper – VII: Dept. Core	ME-5212	Additive Manufacturing Technology	3	0	0	3	100
3	Paper – VIII: Dept. Core	ME-5213	Micro & Nano Manufacturing	3	0	0	3	100
4	Paper – IX: Dept. Elective	List below	List below	3	0	0	3	100
5	Paper – X: Open Elective	SUBJECT OFFERED BY OTHER DEPARTMENTS		3	0	0	3	100
Theory Subtotal							**15**	**500**
6	M. Tech. Project Part - I	ME-5291	M. Tech. Project Part - I (Term Paper)	0	0	4	4	200
7	Seminar & Viva-voce	ME-5292	Term Paper Seminar & Viva-voce	0	0	2	2	100

Practical Subtotal	**6**	**300**
Second Semester Total Credit	**21**	**800**

List of Departmental/Open Electives for Second Semester

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

C. Third Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	M. Tech. Project Part - II	ME-6191	M. Tech. Project Part - II (Progress Report)	0	0	12	12	300
2	Seminar & Viva-voce	ME-6192	Progress Report Seminar & Viva-voce	0	0	6	6	100
Practical Subtotal							**18**	**400**
Third Semester Total Credit							**18**	**400**

D. Fourth Semester

Sl. No.	Paper	Subject Code	Name of the Subject	Load/Week			Credit	Marks
				L	T	P		
1	M. Tech. Final Thesis	ME-6291	M. Tech. Final Thesis	0	0	22	22	400
2	Seminar & Viva-voce	ME-6292	Thesis Seminar & Viva-voce	0	0	8	8	200
Practical Subtotal							**30**	**600**
Fourth Semester Total Credit							**30**	**600**

Course Curriculum
for
Thermal Science and Energy Technology

Advanced Engineering Thermodynamics (ME5101)

1st Semester

Credit: 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Sl. No.	Topics	No.of lectures
01	Review of Thermodynamics Laws: First law efficiency, Reversibility, Clausius inequality, Principle of increase of entropy, Entropy change due to mixing of fluids, Entropy generation	06
02	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	06
03	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	06
04	Thermodynamics Relations: Maxwell's equations, Different TdS equations, Relation between different heat capacities, Energy equation, Joule-Kelvin effect, Inversion curve, Clausius Clapeyron equation, Mixture of variable composition, Gibbs phase rule	06
05	Reactive Systems: Degree of reaction, Reaction equilibrium, Law of mass action, Heat of reaction and enthalpy of combustion, Nernst'sequation, Thermal ionization of mono-atomic gas, Saha's equation, Adiabatic flame temperature, Fugacity and activity, Second law analysis of reactive system	06
06	Analysis of Engineering cycles: Combined cycle and cogeneration	03
	Total	**33**

Text Books:

1. Nag,P.K.EngineeringThermodynamics,FifthEdition,2013,McGraw-HillEducation(India)Private Limited

2. Boles,M.AandYungusA.Cengel,Y.A.Thermodynamics:AnEngineeringApproach,EighthEdition, 2015, McGraw-Hill Education (India) Private Limited

Reference Books:

2. 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, Fourth Edition, 1992, Pergamon

Solar, Wind and Biomass Energy Systems (ME5102)

1st Semester

Credit–3 **FullMarks:100**

ContactPeriod:3-0-0 (L-T-P) **Course Type: Departmental Core**

Sl. No.	Topics	No. of lectures
01	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.	**6**
02	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	**6**
03	Fundamentals of photovoltaic conversion, Efficiency of solar cells, Solar modules and array, Balance of system (BOS), Standalone system, Grid independent system, Grid interactive system, Photovoltaic applications	**6**
04	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	**6**
05	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.	**6**
06	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.	**3**
	Total	**33**

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

Advanced Fluid Mechanics (ME5103)

Credit – 3 **Full Marks: 100**
Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Sl No.	Topics	No. of lectures
1.	**Introduction:** Properties of fluid , Continuum hypothesis, Real life viscous flow phenomena, Laminar and Turbulent Flow, Tensor notations, Lagrangian and Eulerian Methods, Streamline, Path line, Streak line, Material Derivative and acceleration, Strain Rate, Translation, Rotation and Distortion of Fluid Element, Vorticity and Circulation.	03
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
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.	06
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.	05
5.	**Flow Instability:** Instability, Concept of Small-Perturbations, Linearized Stability of Parallel Viscous Flows, Orr-Sommerfeld Equation, Neutral Stability Curve, Boundary Layer Transition over a Flat Plate,	03
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 Sublayer, Power Law for Turbulent Boundary Layer, Skin Friction Coefficient, Turbulent Boundary Layer with Pressure Gradient, The dynamic of Turbulence.	04
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
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.	05
	Total	33

References:

1. Fluid Mechanics by Pijush K. Kundu, Ira M. 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)

Combustion Science &Technology (ME5121)

1st Semester

Credit–3 **Full Marks: 100**

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl No.	Topics	No. of lecture periods
01	Introduction to combustion; Applications of combustion, Various modes of combustion, Scope of combustion.	02
02	Review of Thermodynamics: Thermodynamics properties, Laws of thermodynamics, Stoichiometry, Thermo-chemistry, adiabatic temperature, enthalpy of combustion and heating values, chemical equilibrium	04
03	Chemical kinetics. Reaction Kinetics, Global and Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism.	04
04	Conservation equations for reacting flow: Fundamental laws of transport phenomena, Conservations Equations.	03
05	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	06
06	Diffusion Flame: Gaseous Jet diffusion flame, Liquid fuel combustion, Atomization, Spray Combustion, Solid fuel combustion	04
07	Combustion and Emission: Atmosphere, Chemical Emission from combustion, Quantification of emission, Emission control methods	05
08	Introduction to turbulent premixed and diffusion flames.	03
09	Combustion instabilities.	02
Total		33

References:

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

Design of Refrigeration and Air-Conditioning Systems (ME5122)

1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topics	No. of periods
1	Refrigeration systems: Vapour compression, multi-pressure, cascade, vapour absorption. Enthalpy concentration diagram. Low temperature refrigeration. Other refrigeration systems.	10
2	Component design of vapour compression refrigeration system: Condenser, compressor, evaporator, expansion devices.	8
3	Refrigerant properties. Ozone layer depletion and global warming	4
4	Psychometry of air-conditioning processes.	2
5	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.	10
6	Duct design. Transmission and distribution of air. Fan design.	6
7	Heat pumps and their applications.	3
Total		43

Text books:

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

Gas Turbine and Jet Propulsion (ME5123)

1st Semester

Credit: 3 **Full Marks: 100**

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl No.	Topics	No.oflecture
01	Introduction to Gas Turbine Cycles: Ideal and actual cycles, Effects of reheating,after-cooling,multi-stagingandheatexchanger,Isentropicand polytropic efficiency, Static and stagnation properties of gases	04
02	Principles of Jet Propulsion: Momentum thrust, Pressure thrust, Turbojet engine, Turboprop-engine, Supersonic jets and ramjets, Turbofan engine	04
03	Centrifugalcompressor:Elementsofcentrifugalcompressor,Flowthrough centrifugal compressors, Impeller and diffuser, Slip factor, Compressibility effect, Loses in compressor, Centrifugal compressor characteristics, Surging and choking.	05
04	Axial Flow Compressor: Elements of axial flow compressor, Principle of operation, Axial compressor stages, Factors affecting stage pressure ratio, Work done factor, Degree of reaction, Losses and efficiency, Off design performance, Single and multistage compressor characteristics, Three dimensional flow, Radial equilibrium theory	05
05	Combustion: Types of combustion chamber, Combustion mechanism and important combustion parameters, Design of combustion system and design parameters. Pressure loss, Combustion efficiency, Combustion stability, Fuel-air ratio, Fuel injection system.	04
06	Turbine: Introduction, Two-dimensional cascade analysis, Workdone, Degree of reaction, Losses and efficiency. Multi-staging of Turbine, Vortex flow theory, Turbine cooling	06
07	Matching of Components: Dimensional analysis for component matching, Engine design point operations, Engine off design operations, Engine operating lines	05
	Total	**33**

Text Books:

1. Saravanamuttoo, H.I.H., Rogers G.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-HillEducationPvt. Ltd.

Greenhouse Technology (ME 5124)

Credit–3 Full Marks:100

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topics	No. of Lectures
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.	6
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.	6
3.	Greenhouse Microclimate Greenhouse heating, cooling, shedding and ventilation systems; Carbon Dioxide generation and monitoring and lighting systems, instrumentation & computerized environmental Control Systems.	6
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.	6
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.	6
6	Cost analysis Cost of production, market economics, growth rate, pay-back analysis	3
	Total	33

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.

Energy, Environment & Economics (ME 5125)

1st Semester

Credit–3 **Full Marks: 100**

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topic	Hours
01	Global Trends in Energy Use, Energy Flow Diagram, Emission Factor, Energy & Quality of Life, Energy Inequality, Energy Demands,Energy Security.	6
02	Issues with Conventional Energy Resources: Resource Depletion, Environmental Impacts, Renewable Energy Sources, Resource Distribution, Energy Mix, Challenges.	6
03	Energy & Environment, Effect of Pollutants, Climate Change & Global Warming, Mitigating Challenges; Frameworks of Action: Ethics	6
04	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;	6
05	Techno-economic and exergo-economic assessments; exergo-environmental assessment, Life Cycle Assessment, Cost of Carbon Emission, Carbon Credits	6
06	Sustainability, Energy Policy, Global and local initiatives	3
	Total	33

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

Nuclear Power Engineering (ME 5126)

1st Semester

Credit–3 **Full Marks: 100**

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topics	No. of Lectures
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.	8
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.	5
3.	Reprocessing Nuclear Fuel Cycles -Spent Fuel Characteristics -Role of Solvent Extraction in Reprocessing Solvent Extraction Equipment.	4
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.	6
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.	6
	Environment & Cost analysis Environmental impact, Accident history, Cost of construction and production, pay-back analysis	3
	Total	33

Text Books:

1. Thomas J. Cannoly, "Fundamentals of nuclear Engineering" John Wiley 1978.

2. CollierJ.G., and HewittG.F, "Introduction to Nuclear power", Hemisphere Publishing, NewYork, 1987.

3. "Nuclear Energy - An Introduction to Concepts, Systems and Applications of Nuclear Process" 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.

(http://web.mit.edu/nuclearpower/).

Hydrogen Energy & Fuel Cells (ME5201)

2nd Semester

Credit–3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Module	Topics	No of lectures
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	4
Production & Separation	Methods of hydrogen production: chemical, thermochemical, electrolytic, direct solar water splitting, biological, Hydrogen separation and purification (Pressure swing adsorption, solvent based absorption, membrane separation and cryogenic separation etc.)	4
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).	4
Overview of Fuel Cells	Electrochemical conversion and Fuel Cells, History, Classification, Work Potential, Reversible Voltage, Nernst Equation, Irreversibilities–Activation Ohmic and Concentration overpotentials; Fuel Crossover and Internal Currents, Thermal and Mass Balances, Efficiency and fuel utilization.	4
Proton Exchange Membrane Fuel Cells	Polymer Electrolyte; Electrodes, MEA, Bipolar Plate and fuel cell stacks; Water Management; Cell Cooling and Air Supply; Systems and applications.	2
Alkaline Electrolyte Fuel Cells	Construction and operating principle, Operating Pressure and Temperature, Electrodes, Cell Interconnections, Current status and applications.	2
Direct Methanol Fuel Cells	Anode Reaction and Catalysts; Electrolyte and Fuel Crossover; Cathode Reactions and Catalysts; Methanol Production, Storage, and Safety; Applications	2
Solid oxide fuel cell (SOFC)	Construction and operating principle; Components, Design and Stacking Arrangements; Performance, Systems and applications	2
Molten carbonate fuel cell (MCFC)	Construction and operating principle; Components, Design and Stacking; CO2 transport and recycling; Performance, Systems and applications.	2
Reversible Fuel Cells	Principle of operation, types, performance and efficiency, systems and applications.	2
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.	3
Economics & Environmental Impacts	Economics of Hydrogen and fuel cells, LCA, Emission reduction potential and environmental assessment, Policy issues.	2
	Total	33

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

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.

Advanced Energy Storage Systems (ME5202)

2nd Semester

Credit–3 **Full Marks: 100**

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Core**

Sl. No.	Topics	No. of periods
01	Need for energy storage, Electrical energy storage system- Battery types and parameters, Lead Acid battery cycle, Nickel Cadmium, Sodium Sulphur and Lithium ion battery, Mathematical modeling of lead acid battery, Battery charging, Battery parameters, Metal air batteries, Designer's choice of battery, ultra and super capacitor	06
02	Hydraulic Energy Storage, Dams and types of Dam, spillways	02
03	Super conducting Magnetic Energy Storage (SMES)	02
04	Mechanical energy storage device- flywheel, compressed air storage system. Pump storage plants.	04
05	Chemical Energy storage- Bio-fuels and Hydrated Salts, Accumulators with internal and external storage. Graphene based composites for electrochemical energy storage	05
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
07	Thermal Energy Storage System- Sensible heat storage system, Latent heat storage system, Thermo-chemical energy storage. Solar Pond and types. Basics of Thermo-electric generator. Heat Pipes and Vapour Chambers.	05
08	Economics of the Energy Storage	04
Total		33

Text Books:

1. Energy Storage Systems by David Elliott, IOP Publishing Ltd. Bristol, UK, 2017. ISBN 978-0-7503-1531-9 (ebook).

2. Storing Energy Ist Edition by Trevor Letcher, Imprint Elsevier, 2016, Hardcover ISBN: 9780128034408,eBook ISBN: 9780128034491.

3. Solar Energy: Principles of Thermal Collection and Storage by S. P. Sukhatme and J.K.Nayak, Tata Mc Graw-Hill Publishing Company Limited.

Advanced Heat Transfer (ME5203)

2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Sl. No.	Topics	No. of periods
	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.	02
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.	02
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.	03
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.	03
	RADIATION	
5.	Introduction: Radiation characteristics of opaque surfaces, solids, liquids and gases. Radiation equation. Radiation transfer theory.	02
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.	02
7.	Radiative properties of real surfaces and view factors: Crossed- Strings method, inside sphere method and unit sphere method.	02
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.	02
9.	Radiative transfer equation in participating media (RTE). Radiative properties of molecular gases, particulate media and semi-transparent media.	02
10.	Solutions of 1-D gray media, Method of spherical harmonics, Discrete ordinates, Zonal method, Inverse radiative heat transfer.	02
	CONVECTION	
11.	Equations of continuity, motion, energy and mass diffusion	01
12.	One-Dimensional solutions	01
13.	Laminar heat transfer in ducts	01
14.	Laminar boundary layers	01
15.	Integral methods	01
16.	Turbulence fundamentals	01

17.	Turbulent boundary layers	01
18.	Turbulent flow in ducts	01
19.	Natural convection	01
20.	Boiling	01
21.	Condensation	01
TOTAL		33

Recommended 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

Numerical Heat Transfer and Fluid Flow (ME5221)

2nd Semester

Credit – 3 **Full Marks: 100**
Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topics	No. of periods
1.	Introduction; Governing differential equations: Meaning of a differential equation, continuity equation, momentum equation, nature of coordinates	04
2.	Discretization methods: Taylor series formulation, variational formulation, method of weighted residuals, control volume formulation, four basic rules	04
3.	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	06
4.	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	8
5.	Computation of flow field: Some related difficulties, representation of pressure gradient term, representation of continuity equation, a remedy by staggered grid, corresponding momentum equations, pressur and velocity corrections, pressure correction equation, SIMPLE algorithm, SIMPLER algorithm.	07
6.	Introduction to commercial CFD codes.	04
Total		33

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. Cumputational 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 Tuncer Cebeci, Jian P. Shao, Fassi Kafyeke, Eric Laurendeau

Energy Efficient Buildings (ME5222)

2nd Semester

Credit–3 **Full Marks: 100**

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Module No.	Topics	No. of Lectures
1.	Solar radiation concept and the Sun earth geometry	03
2.	Building Orientation and design	02
3.	Concept of passive heating and cooling in the buildings	03
4.	Basics of heat transfer in buildings	02
5.	Thermal modeling of the passive concepts	04
6.	Evaporative cooling and methods	03
7.	Day lighting through windows	02
8.	Earth air tunnel and heat exchanger	03
9.	Zero energy Building concepts, practices and rating system	03
10.	Design of Green Building and energy management of buildings	03
11.	Energy Auditing and Radiation Cooling of Building in hot and Dry Climate	03
12.	Simulation Techniques of Energy Conservation in Building	03
		33

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 Milli Majumdar 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.

Cryogenic Systems and Equipment (ME5223)

2nd Semester

Credit–3 **Full Marks: 100**

Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Module	Topics	No. of Lectures
01	Introduction: Introduction to Cryogenic Systems: Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures.	5
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. Critical components in Liquefaction Systems, Introduction to air separation.	8 2
03	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.	6
04	Cryogenic Insulation: Cryogenic Insulation, Multi-layer insulation, Vacuum insulation etc. Applications: Applications of Cryogenic in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications.	6
05	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 andX-raytubes, cryogenic insulation, space simulation	6
	Total	33

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
4. Cryogenic Engineering, R.B.Scott, Van Nostrand and Co.,1962
5. Vacuum Science and Technology, V.V. Rao, T.B. Ghosh, K.L. Chopra, Allied Publishers Ltd., New Delhi.
6. Vacuum Technology, A. Roth, North Holland Publishing Company, Amsterdam.

Distributed Energy Systems & Micro-grids (ME5224)
2nd semester

Credit: 3 **Full Marks:100**
Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topics	No. of Lectures
01	**INTRODUCTION TO DISTRIBUTED GENERATION** Introduction - Distributed Vs Central station Generation-Traditional power systems-T&D system costs-power from Grid as a target for DG- DG planning and comparison: Types of DG Planning Methods-comparison of various types of DG systems.	6
02	**TYPES OF DG's Renewable resource Distributed** Generators-Solar Thermal power Generation-wind powergeneration-Fuel Cell powered DG-Gas Turbine Powered DG-Grid Interconnection optionsTypes of Grid interconnection.	6
03	**MICRO-GRIDS-I** Introduction to micro-grids – Types of micro-grids – Autonomous and non-autonomous grids– Sizing of micro-grids – AC & DC Micro Grids –Comparison- Micro-grids with power electronic interfacing units DG Micro Grid Topologies	8
04	**MICRO-GRIDS-II** DC Power source components, application of DC Microgrids - DC Microgr d operations, Some Standards related with DC Power Circuit -Control methods in DC Micro grid -Linear and nonlinear Stability system in DC Micro-grid.	8
05	**Cost analysis** Cost of electricity, market economics, pay-back analysis	3
	Total	33

Text Books:

1. H. Lee Willis, Walter G. Scott, Distributed Power Generation – Planning and Evaluation, Marcel Decker Press.(unit-1,2,3).
2. Robert Lasseter, Paolo Piagi, Micro-grid: A Conceptual Solution, PESC 2004, June 2004.

Reference Books:

1. F. Katiraei, M.R. Iravani, "Transients of a Micro-Grid System with Multiple Distributed Energy Resources" International Conference on Power Systems Transients (IPST-05) in Montreal, Canada on June 19-23, 2005
2. Z.Ye R. Walling, N.Miller, P.Du.K.Nelson,"FacilityMicrogrids, General Electric Global Research Center, Niskayuna, New York, Subcontract report, May 2005.

NPTEL Link:

Clean Coal Technology (ME5225)

2nd Semester

Credit: 3 **Full Marks:100**
Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topics	No. of Lectures
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	06
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	08
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	06
04	**CO_2 Capture Technologies** Carbon capture: different methods (physical/chemical/biological) of Carbon capture from 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	06
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	07
	Total	**33**

Recommended 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.

Carbon Capture and Storage (ME5226)

2nd Semester

Credit: 3 **Full Marks:100**
Contact Period: 3-0-0(L-T-P) **Course Type: Departmental Elective**

Sl. No.	Topics	No. of lectures
1	**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 footprint, Kyoto and Montreal protocols and Kigali agreement, Intergovernmental panel on climate change (IPCC), Climate change	**06**
2	**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	**06**
3	**CO_2 Capture Technologies** Carbon capture: different methods (physical/chemical/biological) of Carbon capture from 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	**08**
4	**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 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	**06**
5	**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	**07**
	Total	**33**

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, Calin Zamfirescu, 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.

Internal Combustion Engines and Electric Vehicles (Code: ME5227)

2nd Semester

Contact Period: 3-0-0 **Full Marks: 100**
Credit – 3 **Course Type: Departmental Elective**

Sl No.	Topics	No. of lecture periods
1	Components of Battery ignition system, working principle and operation, limitations of conventional breaker operated ignition system and Modern ignition system	03
2	Limitation of Simple Carburetor, Solex, Zenith and SU Carburetor. MPFI Engines and its different Sub-systems	03
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
4	Combustion chamber design principle for SI engines, Types of SI engine combustion chambers and their working.	03
5	Alternate fuels for Internal Combustion Engines and the Engine modifications required to operate the existing engines with the alternate fuels.	02
6	Supercharging and Turbo-charging of Internal Combustion Engines	02
7	Lubricating Oils for IC Engine, Properties of lubricating oil, SAE and API model of classification of lubricating oils, Multi-Grade oils	02
8	Basic difference between a reciprocating IC engine and Gas turbines, Air Breathing Jet Propulsion system and basics of Rocket Propulsion	02
9.	Introduction and Overview of the Electric Vehicle (EV)	01
10.	Types of Electric Vehicles with their merits	01
11.	Vehicle Subsystems, Comparison of ICE and EV	03
12.	Drive cycle, power requirements	03
13.	Introduction to EV battery, battery parameters, BMS, Lithium ion battery, SoS and SoH estimation, Battery pack development and design	03
14.	EV motors and controllers, EV Chargers	02
	Total	**33**

Text Books

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. A course in Internal Combustion Engines by V.M. Domkundwar and A.V. Domkundwar- Dhanpat Rai and Co.-printing 2013.
6. Gas Turbines - V. Ganesan- Tata McGraw-Hill Education Private Limited –Third edition, printing 2010.
7. H.N.Gupta, Fundamentals of Internal Combustion Engines, PHI, New Delhi, 2006.
8. Electric Vehicles Theory and Design, Yiqing Yuan, SAE International
9. 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.

Thermal Simulation Laboratory (ME5171)

Contact Period: 0-0-3 **Full Marks: 100**
Credit – 2

List of Experiments

Sl No.	Topics
1	Familiarization with simulation software: EES/CycleTempo/ANSYS/Aspen
2	Simulation of VCR cycle and calculation of COP using EES/CycleTempo
3	Simulation of boundary layer on flat plate using ANSYS
4	Modelling of combined cycle power plant using CycleTempo
5	Simulation of gasification reactions using Aspen/ CycleTempo
6	Study of combustion thermodynamics using EES
7	Performance analysis of ammonia-water VAR system using EES/Cycletempo
8	Heat exchanger design using Aspen/ANSYS

Renewable Energy Laboratory (ME5172)

Contact Period: 0-0-3 **Full Marks: 100**
Credit – 2

List of Experiments

Sl No.	Topics
1	Study of radiation measuring instruments
2	Measuring solar radiation using Pyranometer and Lux meter
3	Study/Experiment with evacuated tube solar water heater
4	Study/ Experiment with flat plate collector
5	Study of PEM electrolyzer for hydrogen generation
6	Trial run of PEM fuel cell unit
7	Performance assessment of solar hydrogen fuel cell system

Renewable & Alternative Energy Technologies (ME5161)

1st Semester

Credit - 3 **Full Marks: 100**

Contact Period: 3-0-0 **Course Type: Open Elective**

Serial No.	Topics	No. of Lectures
1.	Introduction: Perspective, Environmental impacts of conventional power plants, Advanced technologies for cleaner power from fossil fuels, Renewable energy sources	03
2.	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	03
3.	Fuel Cells: - Introduction, descriptions and classification, Working principles, electrochemistry of H_2-O_2 cells, Nernst eqn. and e.m.f., Overpotentials 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	03
4.	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	03
5	Thermoelectric devices - Working principles, descriptions, emf and figure of merit, efficiency calculations.	03
6.	Biomass energy conversion: Bio-gasification, gas engines, biomass gasification combined cycles (BIGCC).	03
7.	Pumped hydro plants: Principle of operation, Load fluctuations and load leveling, load curve analysis	03
8.	Wind Energy Conversion. Principle of conversion, Types of turbines.	03
9.	Tidal, Wave and Ocean Thermal (OTEC) energy conversion: Basic principles, Description of different types of plants, open and closed OTEC systems	03
10	Geo-thermal energy - Principle of Conversion, geothermal resources, classification of plants.	03
11	Economics and policies of non-renewable energy, environmental assessment, Carbon credit	03
Total		**33**

Recommended References

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 Curriculum
for
Machine Design

Advanced Solid Mechanics (ME5106)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Core

Module	Topics	No. of Lectures
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, Generalised Hook's Law,	06
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
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
Beam-columns	Derivation of fundamental equation for beam-columns, determination of deflection, slope and moment of beam-columns under various loading conditions	03
Beams on elastic foundation	Definition of modulus of elastic foundation, deflection equation of beams, determination of deflection, shear force and moment of infinitely long beam under various loading conditions	03
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
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
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
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
Total:		**40**

Text books:

1. Advanced Mechanics of Solids (3rd Edition) by L. S. Srinath, Tata McGraw Hill, 2009
2. Advanced Solid Mechanics (Part-II) by S. P. Timoshenko, CBS Publications.
3. Theory of Elasticity (3rd Edition) by S. P. Timoshenko and J. N. Goodier, McGraw Hill International
4. Advanced strength of materials by Den Hartog, McGraw Hill

Linear and Nonlinear Vibration (ME5107)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Core

Module	**Topics**	**No. of Lecture**
Introduction	Degrees of freedom, Lumped parameter modeling of systems, Lagrange equation	3
single degree-of-freedom model	Free vibration, Forced vibration, Damped vibration, Resonance, Vibration isolation	6
Two/multi degrees of freedom model	Mass and stiffness and damping matrix, Eigenvalue problem in vibration, Modes of vibration, Modal decomposition method of forced vibration	5
Vibration of elastic bars and shafts	Equation of motion, Natural frequency and mode shapes under different boundary conditions	6
Understanding Nonlinearity	Properties of Linear systems, Sources of Nonlinearity, Linear and Nonlinear Springs, Examples of Different Nonlinear Oscillators, Non-dimensionalization.	4
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	5
General Second-Order Systems	Linearization, Linear Stability Analysis of Fixed Points.	4
Limit Cycle	Definition, van der Pol Oscillator, Existence and Non-existence of Limit Cycle, Liénard equation, Relaxation Oscillator	4
Bifurcations	Static Bifurcations: Turning Point, Transcritical, Pitchfork. Dynamic Bifurcation: Hopf.	3
Nonlinear Stability Analysis	Stability: Lyapunov, Asymptotic, Exponential. Lyapunov Stability Criteria.	2
Total		**42**

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.

Geometric Modelling For CAD (ME5108)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Core

Sl. No.	Topics	No. of lecture
1	Basics of CAD and terminology, Raster and vector image, Basics of transformation, Data format : IGES, DXF etc.	04
2	Non-parametric and parametric representation of curves, Analytic and synthetic curves.	03
3	Design of synthetic curves: Cubic spline, Bezier and B-Spline curve.	10
4	Basics of surface design: tangent, twist, normal, geodesic etc. Gaussian curvature, criterion for developable surface.	03
5	Design of surfaces: Ruled, Linear and Bicubic Coon's surface, Bezier surface. Operations on surfaces: joining, reparametrization and truncation.	10
6	Solid modeling: terminology, primitives, Boolean operations, Basics of Constructive Solid Geometry and Boundary Representation.	08
7	Programming with AutoLISP , SolidWorks modeling, CATIA	04
Total		**42**

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. AutoLISP Manual; AUTODESK
4. MATLAB: An introduction with application - Amos Gilat; Wiley India

Engineering Tribology (ME5132)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Sl. No.	Topics	No. of Lectures
1	Introduction: a brief history of Tribology, industrial importance	02
2	Engineering surfaces - properties and measurement: surface profilometer, optical microscopy, electron microscopy, statistical and fractal description of surface roughness	06
3	Contact between surfaces: geometry of non-conforming surfaces in contact, surface tractions, surface and subsurface stresses, contact of rough surfaces	06
4	Adhesion at solid-solid contact: adhesion models, factors influencing adhesion, adhesion at the contact between rough surfaces	04
5	Genesis of solid friction, friction theories - simple adhesion theory, modified adhesion theory, deformation theory, measurement tools, friction of metals and non-metallic materials	06
6	Mechanisms of Wear: adhesive wear, abrasive wear, erosive wear, cavitational wear, chemical wear, surface fatigue wear, wear of metals, non-metallic and composite materials	06
7	Thermal considerations in sliding contact: measurement of surface temperature in sliding, theoretical analyses	04
8	Tribo-testing tools: measurement of friction and wear	02
9	Lubrication regimes: thick-film and thin-film lubrication	06
Total		**42**

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.

Applied Elasticity and Plasticity (ME5133)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Sl. No	Module	Content	No of Lectures
1.	Review of stress analysis	(a) Stress tensor and Traction vector. Coordinate rotation & transformation of stress tensor, Principal stress and Principal coordinate, Maximum shear stress, Shear stress in octahedral plane, (b) Strain displacement relation, Compatibility condition, (c) Stress Strain relation, Generalized Hook's Law (d) Equilibrium eq. in Cartesian and curvilinear co ordinates	03+01+01 +02 = 07
2.	Stress Function	Concept of stress function, Solution of 2D elasticity problems using stress function in i) Cartesian and ii) polar co-ordinate.	05
3.	Strain Energy	Concept of strain energy, Principle of virtual work and associated problem of 2D elasticity	03
4.	Plastic Yielding & flow	(a) Yield function and its physical interpretation, Yield surface and Yield locus, Tresca and von-Mises yield function. Geometric interpretation of Tresca and von-Mises yield surface and yield locus, von-Mises equivalent stress and equivalent plastic strain, Plastic work (b) Flow rule: Prandle Reus equation, Levy Mises equation, Normality condition & associated flow rule. Plastic potential & Hill's principle of maximum dissipation. Stress Strain relation of elastic-plastic material	05 +05 =10
5.	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	05
7.	Analytical techniques for elastic perfectly plastic material	i) Bending of prismatic beam ii) Torsion of prismatic bar iii) Thick cylinder with internal pressure	05
8.	Plane strain problem	i) Slip line theory and its application ii) Solution of 2D metal forming problem by slip line theory	04
9.	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
Total			**42**

Text books:

1. Theory of Elasticity: - S. P. Timoshenko and J.N. Goodier
2. Theory of Plasticity: - J. Chakraborty
3. Plasticity for Engineers - Johnson and Mellor

Ref. Book:

1. Plasticity - L. M. Kachanov

Advanced Mechanics of Machines (ME5134)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Module	**Topics**	**No. of Lectures**
Introduction I	Introduction to mechanisms, Applications of mechanisms, Kinematics of mechanisms – kinematic diagrams, Degree of freedom.	4
Introduction II	Position and displacement analysis –graphical methods, Velocity analysis –relative motion–graphical method – instant center, Mechanical advantage, Acceleration analysis –graphical method.	4
Advanced Kinematics of Plane Motion - I	Introduction to plane motion. The Inflection circle, Euler –Savary Equation, Analytical and graphical determination of di, Bobillier's Construction, Collineation axis, Hartmann's Construction.	4
Advanced Kinematics of Plane Motion - II	Inflection circle for the relative motion of two moving planes, Application of the Inflection circle to kinematic analysis.	2
Advanced Kinematics of Plane Motion - III	Polode curvature, Hall's Equation, Polode curvature in the four bar mechanism, coupler motion, relative motion of the output and input links, Determination of the output angular acceleration and its Rate of change.	5
Advanced Kinematics of Plane Motion - IV	Freudenstein's collineation –axis theorem, Carter –Hall circle, The circling – point curve for the Coupler of a four bar mechanism.	2
Introduction to Synthesis- Graphical Methods - I	The Four bar linkage, Guiding a body through Two distinct positions, Guiding a body through Three distinct positions, The Roto center triangle, Guiding a body through Four distinct positions, Burmester's curve.	5
Introduction to Synthesis- Graphical Methods - II	Function generation- General discussion, Function generation: Relative – Roto center method, Overlay's method, Function generation- Velocity – pole method, Path generation: Hrones's and Nelson's motion Atlas, Roberts's theorem.	6
Introduction to Synthesis - Analytical Methods I	Function Generation: Freudenstien's equation, Precision point approximation, Precision – derivative approximation.	2
Introduction to Synthesis - Analytical Methods II	Path Generation: Synthesis of Four-bar Mechanisms for specified instantaneous condition, Method of components, Synthesis of Four-bar Mechanisms for prescribed extreme values of the angular velocity of driven link, Method of components.	6
Total		**40**

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.

Design Optimization (ME5135)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Module	Topics	No. of Lectures
1	Introduction and overview of optimization problems including the notion of convergence and convexity	3
2	Basics of univariate unconstrained minimization	3
3	Fundamentals of multivariate optimization including equation solving and least squares problem	4
4	Discussion of professional (applied) methods for multivariate optimization	4
5	Basics of constrained optimization	6
6	Linear programming problems	3
7	Quadratic programming problem	5
8	Different family of methods for solving a constrained optimization problem	6
9	Advanced topics	6
Total		**40**

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.

Biomechanics (ME5136)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Sl. No.	Topics	No. of Lectures
1.	Introduction to Biomechanics - Basic terminologies, applications, concept and function of human musculoskeletal system, review of basic Mechanical Engineering concept	04
2.	Musculoskeletal system – composition, structure, function, and biomechanical behaviour of bone, cartilage, muscle, ligament and tendon.	06
3.	Biomechanics of human joints – structure, range of motions and musculoskeletal model of forces for human joints (hip, knee, ankle, shoulder, elbow and spine).	08
4.	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
5.	Bone remodeling, fracture healing in bone, mechanobiology based bone ingrowth, tribology of synovial joints.	06
6.	Human motion and gait analysis - Joint kinematics, gait cycle, measurement techniques in gait analysis, estimation of musculoskeletal forces, example applications.	08
Total		**42**

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.

Reference Books

1. Biomechanics - Mechanical Properties of Living Tissue, YC Fung, Springer Verlag, 1993.

2. Fundamentals of Biomechanics, 2nd Edition, D Knudson, Springer, 2017.

Industrial Robotics (ME5162)

For M. Tech. (Machine Design) 1st Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Open Elective

Module	**Topics**	**No. of Lectures**
Introduction	Definition, Law of Robotics, Anatomy of a Robot, Robot Classification, Geometric Configurations, Robot Specifications.	2
Robot Drive System	Introduction to Actuators, Electric Actuators	2
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
Differential Motion and Velocity	Differential Motions of Frames and Robot Joints, Robot Jacobian, Inverse differential Kinematics.	4
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
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.	5
Trajectory Generation	Joint Space Schemes: Polynomial Trajectories.	2
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).	2
Industrial Applications	Application of Robots in Material Handling, Machine Loading and Unloading, Welding, Spray Painting. Robotic Assembly. Safety in Robotics.	1
Total		**42**

References:

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.
2. R. K. Mittal and I. J. Nagrath, Robotics and Control, Tata McGraw-Hill, New Delhi, 2007.
3. K. S. Fu, C. S. G. Lee and R. Gonzalez, Robotics: Control, Sensing, Vision and Intelligence, Tata McGraw-Hill Education, 1987.
4. S. K Saha, Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2014.
5. S. R. Deb and S. Deb, Robotics Technology and Flexible Automation, Tata McGraw-Hill, New Delhi, 2010.
6. K. Ogata: Modern Control Engineering, Prentice Education India, 2015.

Fatigue, Creep and Fracture Mechanics (ME5206)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Core

Module	**Topics**	**No. of Lectures**
Fatigue	Concept of Fatigue failure, High Cycle Fatigue, Low Cycle Fatigue (a) 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. (b) Low Cycle Fatigue (Strain-based fatigue) - Hysteresis loop, steady-state loop, cyclic stress - strain curve, Coffin-Manson 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 (c) Fatigue damage accumulation and life exhaustion, Linear damage rule (Palmgren Miner Rule), cycle counting methods	14
Creep	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
Fracture Mechanics	Introduction on fracture failure, brittle and ductile types of failure, strain energy release rate, Griffith's theory of crack propagation, condition for crack growth, types of mode of loading for fracture, concept of stress intensity factor, estimation of stress and displacement fields around the crack tip for various modes of loading, concept of J-integral for characterizing of crack, Ramberg - Osgood's relation for plastic fracture mechanics, estimation of near-field J-integral, Irwin's approximation and Dugdale's approach for the extent of plastic zone, configuration of plastic zone as per Von-Misses criterion and Tresca criterion for plane stress and plane strain conditions, maximum tangential stress and maximum strain energy density criterion for mixed mode crack propagation	16
Total		**40**

Text books:

1. Fatigue of Metals - S. Suresh
2. Fundamental of creep in metals & alloys - M. E. Kassner
3. Fracture Mechanics – Fundamentals and Application – T. L. Anderson
4. Elementary Fracture Mechanics - David Broek
5. Elements of Fracture Mechanics - Prasanta Kumar

Control of Mechanical Systems (ME5207)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Core

Module	**Topics**	**No. of Lectures**
Introduction	Closed-loop and Open-loop control Objectives of Control systems Examples of control systems Laplace Transform	4
Modelling of Control Systems	Frequency domain modelling – Transfer function/Transfer Matrix Concept of Poles and Zeros Block Diagram Time Domain Modelling – State-space representation	8
Response Analysis	Time-domain and Frequency-domain response of first, second and higher order systems	6
Characteristics of control systems	Sensitivity, Disturbance/Noise rejection, Steady-state accuracy, Stability analysis	6
Design of controller	Pole-placement, PID, Internal Model Controller, LQR	5
Controller Design for CNC and Robotic Devices	PID Control for CNC and Robotic Manipulator	3
Vibration Control	Active Vibration Control	4
Nonlinear Control	Describing Function, Feedback Linearization, Sliding Mode Control	4
Total		40

Text Book:

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

Computational Mechanics of Solids (ME5208)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Core

Module	**Topics**	**No. of Lectures**
Introduction to Computation by Numerical Methods	Numerical Methods and its relevance in Engineering, Different Numerical Methods and their Utilities	1-2(2)
Fundamentals of FDM and FEM	Basic concepts of the FD and FE Methods and their Differences, Versatility of FE method over FD method.	3(1)
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.	4-6(3)
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.	7-11(5)
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.	12-17(6)
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.	18-23(6)
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.	24-28(5)
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.	29-34(6)
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.	35-38(4)
Demonstration of an FE commercial Package	Demonstration of an FE Commercial package like ANSYS/ ABAQUS/AUTODYN (any one).	39-40(2)
Total		**40**

Text Books:

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. Introduction to the Finite Element Method (3rd Edition) by J.N. Reddy, Tata McGraw-Hill, 200.

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.

Introduction to Modern Materials (ME5231)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Module	Topics	No. of Lectures
Composite Materials: Definition, Classification	Definition of composite materials with examples, classification of composites, comparison with conventional metals.	03
Rule 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
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
Fabrication of Composite Materials	Manufacturing of composites: laminate casting, helical winding, Polar winding and pultrusion process.	02
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
Theories of Failure of Orthotropic Laminae	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
Environmental effects on composites	Environmental effects on composites: thermal and hygroscopic effects	03
Analysis of Composite Laminates	Introduction to composite laminates, lamination code, classical Lamination theory based on Kirchhoff's hypothesis	03
Analysis of Composite Laminates (Contd.)	Specially orthotropic, generally orthotropic, symmetric, anti-Symmetric and quasi-isotropic laminates	03
Design of Composite laminates	Design consideration: Analysis of laminates after first ply failure, Interlaminar stresses, Progressive failure of laminae	03
Property Determination of Composites by Tests	Experimental characterization of composites: tension, compression and various types of in-plane shear tests. Flexural tests with NDT of composites	05
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	04
Total		**40**

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,

Bearing Lubrication (ME5232)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Module	Topics	No. of Lectures
Lubrication Regime	Hydrodynamic lubrication, 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
Circular Step Thrust Bearings	Analysis of capillary and orifice-compensated thrust bearings, optimum value of stiffness of both types of thrust bearings	02
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	04
Hydrodynamic Instability	Introduction on hydrodynamic instability, mechanism of hydrodynamic instability and its preventive measure	02
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	03
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
Thermal Effect on lubricated bearing film	Reynolds equation for thermo-hydrodynamic lubrication, energy equation , thermo-hydrodynamic analysis of Rayleigh step bearings	03
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	04
Total:		**32**

Text Books:

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)

Design of Piping Systems (ME5233)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Module	**Topics**	**No. of Lectures**
Introduction	Introduction to Piping Components and Connecting Equipment, Modes of Failure, Piping Codes basics	2
Strength and Failure of Materials Basics	Elastic Relationship of Stress and Strain, Plasticity, Creep, Fracture and fatigue	4
Pipe Stress Analysis	Codes and Standards, Design Consideration loadings, Basic Allowable stress, Pressure Design, Stresses of Piping Components	5
Thermal Expansion and Piping Flexibility	Thermal Expansion Force and Stress, Methods of Providing Flexibility, General Procedure of Piping Flexibility Analysis, Problems With Excessive Flexibility.	7
Expansion Joints	Basic Flexible Joint Elements and Analytical Tools, Applications of Bellow Expansion Joint, Slip Joints and Flexible Hoses	2
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	5
Piping connected to Rotating Equipment	Pipe Connected to Steam turbines, Centrifugal Compressors, Centrifugal Pumps, Procedure for Designing Rotation Equipment Piping.	5
Transportation Pipeline	Governing Codes and General Design Requirements, Behavior of Long Pipeline, Pipeline Bends	3
Vibration: Prevention and Control	Fundamental Consideration in piping vibration, Structural Natural Frequency Calculation, Damping of structural vibration, Flow pulsation Smoothing, Illustration of Vibration analysis of a simple Piping System	7
Total:		**40**

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.

Non-Destructive Testing of Materials (ME5234)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Module	Topics	No. of Lectures
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.	2
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.	4
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.	5
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.	5
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).	7
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	7

	good radiograph, film processing, interpretation, evaluation of test results, safety aspects required in radiography applications, advantages and limitations of RT.	
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.	6
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.	6
Total:		**42**

Text Books:

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).

Industrial Tribology (ME5235)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Sl. No.	Topics	No. of Lectures
01	Surface Engineering: surface treatments - micro-structural and thermo-chemical treatments, surface coatings - hard facing and vapour deposition processes	05
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, detergent and dispersant additives	08
03	Boundary lubrication: mechanism of boundary lubrication, metal-working lubrication, solid film lubrication, solid lubricants	05
04	Tribology in automotive engineering and coal-fired power plants: case studies of tribo failures	05
05	Wear debris analysis: Ferro graphy and Spectrometric Oil Analysis Program (SOAP)	04
06	Tribology in biomedical engineering: lubrication in natural synovial joints, synthetic cartilage and lubricants, design of joints and prosthetic devices, biomaterials	07
07	Nanotribology: Surface Force Apparatus (SFA), Scanning Tunneling Electron Microscope (STM), Atomic Force Microscope/Friction Force Microscope (AFM/FFM), fabrication techniques for MEM/NEMS	04
08	Green tribology: Biomimetics for tribological applications, surface texturing and environment-friendly lubrication (self, natural and biodegradable lubrication)	04
Total		**42**

Text Book:

1. Engineering Tribology - G. W. Stachowiak and A. W. Batchelor, Elsevier Science Publishers

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

Data-Driven Dynamical Systems (ME5236)

For M. Tech. (Machine Design) 2nd Semester

Credit: 3 **Full Marks:** 100

Contact Period: 3-0-0 (L-T-P) **Course Type:** Departmental Elective

Module	**Topics**	**No. of Lectures**
Introduction	What is Dynamical System, Flows and Maps.	2
Derivation of Equations of Motion	Simple, Externally Forced and Parametrically Pendulum (SDOF), Double Pendulum (2DOF)	3
Linear and Nonlinear Systems	State-space, Fixed Point, Linear Stability Analysis, Limit Cycle.	6
Introduction to Chaos	One Dimensional Map: Fixed Points and their Stability. Numerics with Logistic Map, Lorenz Equations. Definition of Chaos, Lyapunov Exponent, Poincaré Map.	5
Dynamics of a Few Systems	SDOF Pendulum (Simple, Externally Forced, Parametrically), Forced Duffing Oscillator	7
Classical Reduced Order Modeling	Singular Value Decomposition, Galerkin Projection, Proper Orthogonal Decomposition	4
Importance of Data	Non-availability of Mathematical Models, Basic Idea of Machine Learning	5
Data-Driven System Identification	Sparse Identification of Nonlinear Dynamics (SINDy), SINDy using Neural Network	3
Data-Driven Reduced Order Modeling	Dynamic Mode Decomposition (DMD), DMD using Neural Network	3
Linear Embedding of Nonlinear Dynamics	Koopman Spectral Analysis, Koopman Spectral Analysis using Neural Network	4
Total		**42**

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

Industrial Engineering (ME5111)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Module		Topics	Number of Lectures
I.	**Introduction**	Concept of Industrial Engineering, Scope of Industrial Engineering, tools of management science, Managerial economics and accounting.	2
II.	**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.	3
III.	**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.	5
IV.	**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
V.	**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 Alternatives	7
VI.	**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.	7
VII.	**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.	6
		Total	**42**

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:

Khanna, O. P., Industrial Engineering & Management, Dhanpat Rai Publication, 19th edition 2013

Non-Traditional Machining (ME5112)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Serial No.	Topics	No. of lecture periods
Serial No.	**Topics**	No. of lecture periods
1.	Need of Non-traditional manufacturing in the present industrial scenario. Differences between traditional and Non-traditional manufacturing, Classification of Non-traditional manufacturing processes.	04
2.	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.	05
3.	Water Jet Machining (WJM): Equipment, Process principles, Operating parameters, Advantages, Limitations, Different applications.	04
4.	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.	05
5.	Chemical Machining (CHM): Equipment, Process principles, Maskants and etchants, Photo-Chemical Machining Advantages, Limitations, Different applications.	04
6.	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.	06
7.	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
8.	Fundamentals of Laser Beam Machining (LBM), lasing process, Material processing with laser; Fundamentals of Electron Beam Machining (EBM), Process principles, Applications.	04
9.	Introduction to Hybrid machining, Electro-Chemical Grinding (ECG), Abrasive Water Jet Machining (AWJM), Vibration assisted hybrid machining processes, Magnetic field assisted machining processes.	04
	Total	**42**

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. Manufacturing Science by A. Ghosh and A. K. Mallick, 2e, Affiliated East-West Press Pvt. Ltd.
3. Production Technology, HMT, Tata McGraw-Hill Education

Advanced Material Processing Technology (ME5113)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Serial No.	Topics	No. of lecture periods
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
2.	Casting process – Metal fluidity, flow, Principle of gating system design, gating system design, Various elements of a gating 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
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
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
5.	Micro Manufacturing (MM) - Introduction to Micro manufacturing (Micro machining and Micro fabrication), A brief overview on different micro manufacturing processes, Advantages, Limitations, applications	04
	Total	**40**

Text Books:

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 Books:

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

Machine Learning for Mechanical Engineers (ME 5141)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Prerequisite: Basic Knowledge of Calculus (Integration and Differentiation), Concepts of Algorithm and Programming.

SYLLABUS: -

Introduction to machine learning, hard and soft computing, Working of Neural Network, Fuzzy Logic, Hybrid Neuro-Fuzzy system, other emerging approaches, Nature-inspired Metaheuristic optimization algorithms Genetic Algorithms: introduction, mathematical foundation, computer implementation, genetic based machine learning applications.

Detailed Module wise Distribution

Sl. No.	Module name with Topics	No of Hours
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;	04
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	06
3	Crisp and Fuzzy Set, Membership function, Fuzzy logic controller: Mamdani Approach, Takagi and Sugeno's Approach, Fuzzy Clustering.	06
4	HybridNeuro-Fuzzy modelling, other modelling techniques: Decision trees, Random Forest, Support vector, Lazy Learners etc.	06
5	Optimization, Single, Multi and Many Objective Optimization, Pareto Optimal Front, Non-dominated Sorting Genetic Algorithms (NSGA)	03
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
7	Modelling and Optimization with Some Practice and Assignments	05
Total Hours		**36**

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 BOOKS:

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

Design of Production System (ME5142)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	Number of Lectures
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.	6
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.	5
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.	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 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.	10
Inventory Management and Control	Inventory: need and types, deterministic and stochastic models for inventory management.	8
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.	4
Engineering Economy and Costing	Elementary cost accounting and methods of depreciation; break-even analysis, techniques for evaluation of capital investments, financial statements	3
	Total	**40**

Text books:

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

Industrial Automation (ME5143)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	Number of Lectures
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.	7
Material handling and Identification Technologies	Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems, Overview of Automatic Identification Methods.	5
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.	7
Control Technologies in Automation	Industrial Control Systems, Process Industries Versus Discrete-Manufacturing Industries, Continuous Versus Discrete Control, Computer Process and its Forms.	5
Computer Based Industrial Control	Introduction & Automatic Process Control	3
Building Blocks of Automation Systems	LAN, Analog & Digital I/O Modules, SCADA Systems& RTU	3
Distributed Control System	Functional Requirements, Configurations & some popular Distributed Control Systems	4
Modeling and Simulation for Plant Automation	Introduction, need for system Modeling, Building Mathematical Model of a Plant, Modern Tools & Future Perspective	4
Industrial Control Applications	Cement, Thermal, Water Treatment & Steel Plants	3
	Total	41

Text books:

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

Quality Engineering (ME5144)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	Number of Lectures
1	Quality Concepts and Scope; Quality of Design and Quality of Manufacturing; Quality Costs and Analysis.	4
2	Quality Analysis-Cause-Effect Relationship, Ishikawa Diagram.	2
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	6
4	Quality in Design-Standardization, Tolerating-Components to Assembly.	3
5	Quality in Processing-Process Capability, Process Planning.	3
6	Process Control-Statistical Process Control and Control Charts.	3
7	Sampling Plans-Scheme, Types, OC Curves.	3
8	Quality in Packing-Installation and Maintenance.	3
9	Quality Loss Functions; Noise Factors and Analysis; Concepts of Robust Design.	4
10	Design of Experiments-Factors and Analysis, One and Two Way Layouts, Latin Square, Orthogonal Array Designs, Optimal Design, Taguchi Methods.	5
11	Reliability-Measurement, Analysis, Allocation and Improvement.	3
12	Industry 4.0:Introduction, Evolution of Industry from 1.0 to 4.0, IIoT, Nine Pillars of Technological Advancement, Smart Manufacturing Use Cases, Benefits of Adopting an Industry 4.0 Model	3
	Total	42

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

Mechanical Testing and Characterization (ME 5145)

For 1st Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Prerequisite: Basic Strength of Materials, Machine Design, Basic Metallurgy, Preliminary Knowledge of FEM.

SYLLABUS: -

Introduction to effect of material processing on properties, Fundamentals of crystallography and lattice strictures, Destructive and Non-Destructive Mechanical testing, Metallographic inspection, Optical Metallography techniques and spectroscopy, Diffraction Methods like SEM, TEM, EBSD, Surface roughness analysis

Detailed Module wise Distribution

Sl. No.	Module name with Topics	No of Hours
1	Introduction, Material Modification with MetalWorking (Forging, Rolling, Casting, Welding, Solidification etc.), Theories of elasticity and plasticity	07
2	Fundamental of crystallography, Lattice Structures, Lattice Defects, Slip, Stacking Faults, Strain Hardening	05
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
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 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	12
Total Hours		36

TEXT BOOK:

1. George Ellwood Dieter - Mechanical Metallurgy (1988).

REFERENCE BOOKS:

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 Characterization of Materials by: E. N. Kaufmann

Computerized Manufacturing (ME 5211)

For M.TECH 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Core**

Module	Topics	Number of Lectures
CNC machines	Introduction to Numerical control of machine tools: Types of CNC machines, Main components of CNC machines.	6
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.	6
CAD to CAM	Automated CNC code generation (without manual programming). Application with CNC Milling and Wire EDM	4
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.	4
Material handling for computerized manufacturing	Types : Industrial Robots (basics only) ; Palletizing station; Conveyors, AS/RS; AGV	4
Tools for CNC machines	Basics of tool geometry and terminology; Types of CNC cutting tools to make quality precision parts: Drill Bits; 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; Materials used in CNC machine cutting tools.	4
Economics of CNC machining	CNC Machining costs: Strategies for cost-saving and time-saving; Calculation of CNC machining costs; Sustainable CNC machining operations.	4
High Speed Machining (HSM)	Definition of HSM, applications, advantages and limitations, Machine features and control for HSM, Tools and tool holder	2
	Total	34

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. Manufacturing Processes –S. Kalpakjian, S.R. Schmid, PEARSON, New Delhi.
2. High Speed Machining - Kapil Gupta, J. Paulo Davim: Elsevier Pub.,
3. CNC Machining Handbook: Building, Programming and Implementation - Alan Overby; McGraw Hill Pub.
4. Metal Cutting Principles – M.C. Shaw, Oxford University Press, Indian Addition, Kolkata

Additive Manufacturing Technology (ME 5212)

For 2nd Semester

Credit: 3 **Marks: 100**

Contact Hours: 3-0-0 **Course Type: Departmental Core**

SL. No.	Topics	No. of lectures
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
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
3.	**Vat Photo polymerization AM Processes:** Stereolithography (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
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
5.	**Sheet Lamination AM Processes:** Bonding Mechanisms, Materials, Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), Gluing, Thermal bonding, LOM and UC applications.	04
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, Applications of Powder BedFusion Processes, Selective Laser Melting (SLM)	06
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
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
	Total	**41**

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 Book:

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.

Micro & Nano Manufacturing (ME 5213)

For 2nd Semester

Credit: 3 **Marks: 100**

Contact Hours: 3-0-0 **Course Type: Departmental Core**

Syllabus:

Introduction to micromachining and nanotechnology, Different fabrication processes, Components of Micromachines, Microdrip fabrication, Mesoscopic domain of micro-machines, Fabrication of devices with high-precision nano-features on metals and semiconductors, Nanomaterials

Lesson Plan:

SL. No.	Topics	No. of lectures
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
2.	Different fabrication processes: Silicon process, LIGA process, Precision Machining Processes- Laser-Assisted Etching, Photoforming, Stereolithography, Electrochemical Micromachining, etc.	06
3.	Components of Micromachines: Microsensors, Microfittings, Microactuators- electromagnetic, electrostatic, piezoelectric, and thermally and photothermally actuated micromechanisms, Microfluidic devices.	06
4.	Microdrip fabrication, Micromanufacturing using electron microscopes, Handling of micro components with laser tweezers, etc., Microfinishing Processes like honing, lapping, superfinishing, burnishing.	06
5.	Mesoscopic domain of micromachines- Introduction, biological systems, cells as machines, role of proteins, physics of micromechanism, future prospects.	05
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 biological system based nanofabrication.	06
7.	Nanomaterials, such as carbon nanotube (CNT) or graphene, etc. Their uses in various manufacturing applications.	06
	Total	41

Text Books:

1. I. 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 Book:

1. J.A. McGeough, Micromachining of Engineering Materials, Taylor & Francis Inc, 2001.
2. B. Bhattacharyya, Electrochemical Micromachining for Nanofabrication, MEMS and Nanotechnology, 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.

Quantitative Techniques in Production Management (ME5241)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	Number of Lectures
1	Historical overview of operations research, fundamentals of OR Modelling, Overview of Project Management, Network analysis for time management (CPM, PERT, Crashing and Simulation)	6
2	Project Resource Management: Allocation, Levelling, Smoothing methods.	4
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.	7
4	Nonlinear programming, Sequential Linear Programming, Indirect method, Interior and exterior penalty Function, Karush-Kuhn Tucker conditions, Applications.	4
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.	6
6	Introduction of robust design, Monte-Carlo Sampling, Design under uncertainty, Reliability analysis, Taguchi methods.	6
7	Multi-objective optimization, Grey relation analysis, principal component analysis, Weight sum optimization, Weak and strong dominance, Pareto front computation, Goal programming and iso-performance, Multi-attribute Utility Theory.	7
	Total	40

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

Operations Management (ME5242)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	Number of Lectures
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	3 L
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	4 L
Production planning and control	Different types of production systems: Mass, Batch, Job, Project and continuous.	2 L
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	5 L 2 L
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, Assembly line balancing: Line efficiency, balance delay, smoothing index, Different techniques of balancing,	6 L
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	5 L
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.	3 L
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.	4 L

	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.	4 L
	Total Classes	42 L

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.

Advanced Material Management (ME5243)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	No. of Lectures
I. Introduction	Introduction to materials management, operating environment, supply chain concept, role of material management	2 L
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.	8 L
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.	6 L
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.	6 L
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 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.	8 L
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?	5 L
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.	8 L
	Total Classes	43 L

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

Material Handling (ME5244)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	No. of Lectures
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.	8
II. Materials Handling Equipment	Concepts of Unit Loads, Material handling and Storage equipments 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 equipments in Steel mills, Power plants, Mines, Automobile and Transport Industries, Large scale Constructions etc.,	9
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 feeding mechanisms – Automated inspection and their design	8
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.	8
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.	9
	Total	**42**

Text Books:

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 Books:

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*

Maintenance and Reliability (ME5245)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	Number of Lectures
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.	8
Maintenance policies – preventive maintenance	Maintenance categories – Comparative merits of each category – Preventive maintenance, maintenance schedules, repair cycle – Principles and methods of lubrication – TPM.	7
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	9
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.	8
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 – 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.	8
	Total	40

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*

Advanced Machining Technology (ME5246)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Module	Topics	Number of Lectures
Advanced tool materials	Advanced tool materials: Coated tools, High performance ceramic tools, Cryo treated tools.	4
Determination of cutting forces	Experimental determination of cutting forces: Dynamometry, Piezo-electric dynamometer: Design and construction.	5
Measurements of wear & cutting temperature	Experimental techniques for wear measurements. Modeling and measurement of cutting temperature.	5
Surface Integrity	Surface Integrity: Surface Metallurgy and Surface Topography, Measurement of surface roughness.	4
Advanced grinding	Advanced techniques of grinding and modern grinding wheels.	5
Cutting fluids	Modern application of cutting fluids: Environmental aspects, Cryogenic machining, MQL principle.	6
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.	8
Non-Traditional machining	Introduction to Non-Traditional machining: EDM, ECM, AJM, USM, LBM.	4
	Total	41

Text books:

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

Energy-Beam Processing of Materials (ME5247)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Sl No.	Topics	No. of lecture periods
1	Basic concept of energy-beam processing, power density, spot size and specific processing energy of different energy-beam processes.	05
2	Fundamentals of jet machining, comparison of mechanical jet machining processes with thermal jet machining processes.	05
3	Lasing process, constructional features of laser cavity, laser beam machining, welding, surface treatment and other applications of laser.	10
4	Fundamentals of electron beam processing, equipment used, process parameters, electron beam machining, electron beam welding.	08
5	Ion beam processing, equipment used, process parameters, ion beam machining, ion beam etching.	08
6	Comparison of material processing with continuous beam and pulsed beam, effect of pulse duration, selection of pulse parameters for different material processing operations.	06
	Total	**42**

Text Books:

1. Laser Material Processing - W.M. Steen - Springer-Verlag.
2. Nonconventional Machining - P. K. Mishra - Narosa Publishing House.
3. Nontraditional Manufacturing - G. F. Benedict - Marcel Dekkar Inc.

Reference Books:

1. Modern Machining Processes - P.C. Pandey and H.S. Shan - Tata McGraw Hill.
2. Manufacturing Processes for Engineering Materials - S. Kalpakjian and S.R. Schmid - Pearson Education India Ltd.

Advanced Operations Research (ME5248)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Serial No.	Topics	No. of lecture periods
1.	Role of operation research in production management, A brief Introduction to linear programming, simplex method, Big-M method, Some special cases of LPP	08
2.	Dual simplex method, Concept of Duality, sensitivity and parametric analysis of dual problem, post-optimal analysis, Problems on Dual Problems.	06
3.	A brief introduction on Transportation and Assignment, Industry specific Problems on Transportation and Assignment	08
4.	Parametric linear programming. Network models, project scheduling by PERT-CPM.	06
5.	Queuing models, Game theory	06
6.	Integer and non-integer linear programming, problems on Integer linear programming	04
7.	Dynamic programming, Sensitivity analysis, Revised Simplex method	06
	Total	**44**

Text Books:

1. Operations Research-An Introduction by Hamdy A. Taha, Prentice Hall of India Pvt Ltd

Reference books:

2. Operations Research-Principles and Practice by A Ravindran, Donald T. Phillips, and James J. Solberg. Wiley Student Edition

3. Introduction to Operation Research by Frederick S. Hillier, Gerald J. Lieberman, B. Nag and P. Basu. Tata McGraw-Hill Publication

4. Operations Research by D. S. Hira and P. K. Gupta. S Chand Publication.

Metal Forming (ME5249)

For 2nd Semester

Credit – 3 **Full Marks: 100**

Contact Period: 3-0-0 (L-T-P) **Course Type: Departmental Elective**

Serial No.	Topics	No. of lecture periods
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
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
3.	Forging (classification, equipment, forging in plane-strain, deformation and defects in forging, residual stresses in forging, process details and power calculation)	05
4.	Rolling (classification, equipment, variables, force, deformation and defects in rolling, theories of hot and cold rolling, process details and power calculation)	05
5.	Extrusion (classification, equipment, variables, deformation and defects in extrusion, extrusion under ideal condition, process details and power calculation)	05
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
7.	Modelling techniques for metal forming processes.	05
	Total	**40**

Text Books:

1. Mechanical Metallurgy, GE Dieter, McGraw Hill Company.

Reference Books:

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.