M.Tech

Course Structure and Syllabus

Department of Mechanical Engineering

Indian Institute of Engineering Science and Technology, Shibpur

भारतीय अभियांत्रिकी विज्ञान एवं प्रौद्योगिकी संस्थान, शिबपुर

ভারতীয় প্রকৌশল বিজ্ঞান এবং প্রযুক্তিবিদ্যা প্রতিষ্ঠান, শিবপুর

Howrah 711103, West Bengal, India

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REVISED AS PER THE SUGGESTIONS OF THE BOAC MEETING HELD ON 16 JULY 2019

(WITH NEW COURSE CODE NUMBERS, October 2020)

Contents

COURSE STRUCTURE

A. First Semester

Sl. No	Paper	Credit
1	Paper-I (Dep. Core)	3
2	Paper-II (Dep. Core)	3
3	Paper-III (Dep. Core)	3
4	Paper-IV (Dep. Elec/ Open Elec.)	3
5	Paper-V (Dep. Elec/ Open Elec.)	3
	Theory Subtotal	**15**
6	Lab - I/ Mini Project - I	2
7	Lab - II/Mini Project - II	2
8	Lab - III/Mini Project - III	2
	Practical Subtotal	**6**
	Total Credit	**21**

B. Second Semester

Sl. No	Paper	Credit
1	Paper - VI (Dep. Core)	3
2	Paper - VII (Dep. Core)	3
3	Paper - VIII (Dep. Core)	3
4	Paper-IX (Dep. Elec/ Open Elec.)	3
5	Paper-X (Dep. Elec/ Open Elec.)	3
	Theory Subtotal	**15**
6	M. Tech Project Part - I (Term Paper)	4
7	Term Paper Seminar & Viva-voce	2
	Practical Subtotal	**6**
	Total Credit	**21**

Note:

1. WWXYZZ is the full code of a subject. WW: Department Code (AE, CE, ME, etc.), X: Year (5,6 for MTech and 8 for PhD), Y: Semester Code (1 for odd semester and 2 for even semester), ZZ: 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.
2. Paper – IV, V in 1st Semester and IX, X in 2nd Semester are elective subjects, which are to be selected from the table below. A student may also opt for open electives offered by other departments for second semester M. Tech Students (subject to availability).
3. Open elective subjects, which are offered by ME department can be taken by other department students only but ME students are not allowed to take these subjects. Similarly Mechanical students can take open electives offered by other departments.
4. 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.
5. 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.

C. ThirdSemester

Sl. No	Paper	Credit
1	M. Tech Thesis Part - II (Progress Report)	12
2	Progress Report Seminar & Viva-voce	6
	Total Credit	**18**

Note:
1. 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.

M. Tech Project Part - II

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	ME 6191	M. Tech Thesis Part - II (Progress Report)	24	12	300
2	ME 6192	Progress Report Seminar & Viva-voce		6	100

D. Fourth Semester

Sl. No	Paper	Credit
1	M. Tech Final thesis	22
2	Thesis Seminar & Viva-voce	8
	Total Credit	**30**

Note:
1. 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.

M. Tech Project Part – III

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	ME 6291	M. Tech Final thesis	30	22	400
2	ME 6292	Thesis Seminar& Viva-voce		8	200

Total Credit: 21 + 21 + 18 + 30 = 90

FIRST SEMESTER
Specialization: Thermal Engineering

a) **Departmental Core Papers** for the specialization (Paper – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5101	Advanced Engineering Thermodynamics	3			3	3	100
2	ME 5102	Viscous Flow Theory	3			3	3	100
3	ME 5103	Internal Combustion Engine	3			3	3	100

b) **Departmental Elective Papers** for the specialization (Paper – IV)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5121	Combustion Science and Technology	3			3	3	100
2	ME 5122	Steam Power Engineering	3			3	3	100
3	ME 5123	Gas Dynamics and Propulsion	3			3	3	100
4	ME 5124	Fuel Cell Technology	3			3	3	100

c) **Departmental Labs** for the specialization (Lab – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5171	Thermal Simulation Laboratory			3	3	2	50
2	ME 5172	Advanced Heat Transfer Laboratory			3	3	2	50
3	ME 5173	Advanced Internal Combustion Engine Laboratory			3	3	2	50

FIRST SEMESTER
Specialization: Machine Design

a) **Departmental Core Papers** for the specialization (Paper – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5106	Advanced Solid Mechanics	3			3	3	100
2	ME 5107	Mechanical Vibration	3			3	3	100
3	ME 5108	Engineering Tribology	3			3	3	100

b) **Departmental Elective Papers** for the specialization (Paper – IV)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5131	Applied Elasticity and Plasticity	3			3	3	100
2	ME 5132	Advanced Mechanics of Machines	3			3	3	100
3	ME 5133	Biomechanics	3			3	3	100
4	ME 5134	Finite Element Methods	3			3	3	100
5	ME 5135	Design Optimization	3			3	3	100

c) **Departmental Labs** for the specialization (Lab – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5176	Tribology Laboratory			3	3	2	50

d) **Departmental Mini Projects** for the specialization (Mini Projects have to replaced with Laboratory/Practical)

Sl. No	Subject code	Related Paper Code and Name	Total load (h)	Credit	Marks
1	ME 5177	Mechanical Vibration (ME 5107)		2	50
2	ME 5178	Advanced Solid Mechanics (ME 5106)		2	50

FIRST SEMESTER
Specialization: Manufacturing Science

a) **Departmental Core Papers** for the specialization (Paper – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5111	Advanced Theory of Metal Cutting	3			3	3	100
2	ME 5112	Non-traditional Machining	3			3	3	100
3	ME 5113	Advanced Material Processing Technology	3			3	3	100

b) **Departmental Elective Papers** for the specialization (Paper – IV)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5141	Industrial Engineering	3			3	3	100
2	ME 5142	Design of Production Systems	3			3	3	100
3	ME 5143	Computer Integrated Manufacturing Systems	3			3	3	100
4	ME 5144	Quality Engineering	3			3	3	100
5	ME 5150	Human Resource Management	3			3	3	100

c) **Departmental Labs** for the specialization (Lab – I, II, III)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5181	Metal Cutting Laboratory			3	3	2	50
2	ME 5182	Non-Traditional Machining Laboratory			3	3	2	50
3.	ME 5183	Advanced Material Processing Technology Laboratory			3	3	2	50

FIRST SEMESTER
Open Elective

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5161*	Renewable Energy	3			3	3	100

* ME 5161(Open Elective) is allowed for other department students only

SECOND SEMESTER
Specialization: Thermal Engineering

a) **Departmental Core Papers** for the specialization (Paper – VI, VII, VIII)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5201	Refrigeration and Air-Conditioning	3			3	3	100
2	ME 5202	Advanced Heat Transfer	3			3	3	100
3	ME 5203	Gas Turbines and Compressors	3			3	3	100

b) **Departmental Elective Papers** for the specialization (Paper – IX)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5221	Solar Thermal Engineering	3			3	3	100
2	ME 5222	Numerical Heat Transfer	3			3	3	100
3	ME 5223	Greenhouse Technology	3			3	3	100
4	ME 5224	Cryogenic systems and Equipment	3			3	3	100
5	ME 5225	Nuclear Power Engineering	3			3	3	100
6	ME 5226	Alternative Energy	3			3	3	100
7	ME 5227	Design of Thermal Systems	3			3	3	100

c) **M. Tech Project Part - I**

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	ME 5291	M. Tech thesis Part - I (Term Paper)	8	4	200
2	ME 5292	Term Paper Seminar & Viva-voce		2	100

SECOND SEMESTER
Specialization: Machine Design

a) **Departmental Core Papers** for the specialization (Paper – VI, VII, VIII)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5206	Fatigue, Creep and Fracture Mechanics	3			3	3	100
2	ME 5207	Geometric Modelling For CAD	3			3	3	100
3	ME 5208	Nonlinear Dynamics	3			3	3	100

b) **Departmental Elective Papers** for the specialization (Paper –IX)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5231	Bearing Lubrication	3			3	3	100
2	ME 5232	Dynamics and Control of Mechanical Systems	3			3	3	100
3	ME 5233	Composite Materials	3			3	3	100
4	ME 5234	Design of Piping Systems	3			3	3	100
5	ME 5235	Industrial Tribology	3			3	3	100
6	ME 5236	Mechanical Drives and Control	3			3	3	100
7	ME 5237	Non-Destructive Testing of Materials	3			3	3	100

c) **M. Tech Project Part - I**

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	ME 5291	M. Tech thesis Part - I (Term Paper)	8	4	200
2	ME 5292	Term Paper Seminar & Viva-voce		2	100

SECOND SEMESTER
Specialization: Manufacturing Science

a) **Departmental Core Papers** for the specialization (Paper – VI, VII, VIII)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5211	Energy Beam Processing of Materials	3			3	3	100
2	ME 5212	Advanced Operations Research	3			3	3	100
3	ME5213	Metal Forming	3			3	3	100

b) **Departmental Elective Papers** for the specialization (Paper –IX)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5241	Quantitative Techniques in Production Management	3			3	3	100
2	ME 5242	Operations Management	3			3	3	100
3	ME 5243	Advanced Material Management	3			3	3	100
4	ME 5244	Material Handling	3			3	3	100
5	ME 5245	Maintenance and Reliability	3			3	3	100
6	ME 5246	Industrial Automation	3			3	3	100
7	ME 5247	Advanced Machining Technology	3			3	3	100

c) **M. Tech Project Part - I**

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	ME 5291	M. Tech thesis Part - I (Term Paper)	8	4	200
2	ME 5292	Term Paper Seminar & Viva-voce		2	100

SECOND SEMESTER
Open Elective

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	ME 5261*	Industrial Robotics	3			3	3	100

* ME 5261(Open Elective) is allowed for other department students only

SYLLABUS

(Individual Course Contents)

Course Contents for Thermal Engineering Specialization

Advanced Engineering Thermodynamics (ME 5101)

For 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 periods
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	05
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	09
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	07
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	07
05	Reactive Systems: Degree of reaction, Reaction equilibrium, Law of mass action, Heat of reaction and enthalpy of combustion, Nernst's equation, Thermal ionization of mono-atomic gas, Saha's equation, Adiabatic flame temperature, Fugacity and activity, Second law analysis of reactive system	08
06	Analysis of Engineering cycles: Combined cycle and cogeneration	04
	Total	**40**

Text Books:

1. Nag, P.K. Engineering Thermodynamics, Fifth Edition, 2013, McGraw-Hill Education (India) Private Limited
2. Boles, M. A and Yungus A. Cengel, Y.A. Thermodynamics: An Engineering Approach, Eighth Edition, 2015, McGraw-Hill Education (India) Private Limited

References 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

Viscous Flow Theory (ME 5102)

For Ist 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.	**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.	05
3.	**Exact solutions of Navier-Stokes Equations:** Fully developed Parallel Flow in a Straight Channel, Flow between concentric rotating cylinders, Couette Flow, Flow of two immiscible fluids in a channel, Parallel flow of power law fluids, Lubrication Theory, Hagen-Poiseuille Flow, Unsteady Parallel Flow, Stokes Problems, Similarity Solution and Creeping Flow, Complex variable and Potential flow.	07
4.	**Boundary Layer Theory:** Derivation of 2-D Boundary Layer Equations, Displacement, Momentum and Energy Thickness, Order of Magnitude Analysis, Shape Factor, Momentum-Integral Approach, Boundary Layer Separation, Effect of Pressure Gradient, Boundary Layer Control mechanism, Blassius Solution of Boundary Layer Equation, Kármán-Pohlhausen Method for flow over a flat plate, Kármán-Pohlhausen Method for Non-Zero Pressure Gradient, Waltz's-Approximations.	06
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,	05
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.	06
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

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 Sctllichting (McGraw-Hill)*

Internal Combustion Engines (ME-5103)

For Ist Semester

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

Sl No.	Topics	No. of lecture periods
1.	Review of Introductory Topics: Heat Engine, Basics of Internal Combustion (IC) Engine, Reciprocating and Rotary IC Engines, Classification of IC Engines, First law efficiency of Engine cycle	02
2.	Components of Battery ignition system, working principle and operation, limitations of conventional breaker operated ignition system and Modern ignition system-CDI, Transistor Assisted Ignition system, Electronic Ignition System with magnetic Pick Up, Piezoelectric Ignition System	05
3.	Limitation of Simple Carburetor, Constant choke type and Constant Vacuum type Carburetor, Solex, Zenith and SU Carburetor. Basics of petrol injection system, Throttle Body Injection system, Electronic Fuel Injection System, MPFI Engines and its different sub-systems	06
4.	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, Fuel Injection system in CI Engines	04
5.	Combustion chamber design principle for SI engines, Types of SI engine combustion chambers and their working.	04
6.	Alternate fuels for Internal Combustion Engines and the Engine modifications required to operate the existing engines with the alternate fuels.	03
7.	Supercharging and Turbo-charging of Internal Combustion Engines	02
8.	Friction and sources of engine friction, Lubricating Oils for IC Engine, Properties of lubricating oil, SAE and API model of classification of lubricating oils, Multi-Grade oils	03
9.	Non conventional engines- Gasoline Direct Injection (GDI) Engine, Homogenous Charge Compression Ignition (HCCI) Engine, Common Rail Direct Injection (CRDI) Engine, Variable Compression Ratio (VCR) Engine, Dual Fuel and Multi-Fuel Engine. Performance analysis of non conventional engines.	06
10.	Air Breathing Jet Propulsion system and basics of Rocket Propulsion	05
11.	Pollution monitoring instruments and techniques, Control measures, emission legislations, Engine modifications to reduce emissions	02
Total		**42**

Text Books

1. Internal Combustion Engines Colin R. Ferguson and Allan T.Kirkpatrick, Wiley publishers, printing 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, printing 2004.
4. Internal Combustion Engines -V. Ganesan- Tata McGraw-Hill Education Private Limited -Fourth edition, printing 2013.
5. Internal Combustion Engines by M.L. Mathur and R.P.Sharma-Dhanpat Rai Publications- printing 2016.
6. A course in Internal Combustion Engines by V.M. Domkundwar and A.V. Domkundwar- Dhanpat Rai and Co.-printing 2013.
7. Gas Turbines - V. Ganesan- Tata McGraw-Hill Education Private Limited –Third edition, printing 2010.
8. H.N.Gupta, Fundamentals of Internal Combustion Engines, PHI, New Delhi, printing 2006.

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.

Combustion Science and Technology (ME 5121)

For 1st 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 combustion: Applications of combustion, Various mode of combustion, Scope of combustion.	02
2.	Review of Thermodynamics: Thermodynamics properties, Laws of thermodynamics, Stoichiometry, Thermo-chemistry, adiabatic temperature, enthalpy of combustion and heating values, chemical equilibrium	04
3.	Chemical kinetics. Reaction Kinetics, Global and Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism.	06
4.	Conservation equations for reacting flow: Fundamental laws of transport phenomena, Conservations Equations.	05
5.	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	07
6.	Diffusion Flame: Gaseous Jet diffusion flame, Liquid fuel combustion, Atomization, Spray Combustion, Solid fuel combustion	06
7.	Combustion and Emission: Atmosphere, Chemical Emission from combustion, Quantification of emission, Emission control methods	05
8.	Introduction to turbulent premixed and diffusion flames.	03
9.	Combustion instabilities.	02

References:

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

Steam Power Engineering (ME 5122)
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
Analysis of Steam cycles	Rankine cycle, Carnot cycle, effect of variation of steam condition onplant thermal efficiency, reheating of steam, regeneration, regenerative feed water heating, Carnotization of Rankine cycle, optimum degree of regeneration, Supercritical pressure cycle, Deaerator, typical layout and efficiencies of a steam power plant, Cogeneration of Power and Process Heat, Numerical Problems. Combined cycle power generation: Flaws of steam as working fluid in Power Cycle, Characteristics of ideal working fluid, Binary vapor cycles, combined Cycle plants, gas turbine-steam turbine power plant, MHD-steam power plant, Thermionic-Steam power plant	10
Fuels and combustion	Coal, oil, natural and petroleum gas, emulsion firing, coal – oil and coal – water mixtures, synthetic fuels, biomass, combustion reactions, heat and enthalpy of combustion, theoretical flame temperature, free energy of formation, equilibrium constant, effect of dissociation, Numerical problems.Combustion Mechanisms :Kinetics of combustion, mechanisms of solid fuel combustion, kinetic and diffusion control, mechanisms of pulverized coal combustion and , fuel-bed combustion, fluidized bed combustion, coal gasifiers, combustion of fuel oil or gas or combined gas	10
Steam Power Plant	Basic type of steam generators, fire tube/water tube boilers. economizers, superheaters, reheaters, steam generator control, air preheater, fluidized bed boilers, electrostatic precipitator, fabric filters and bag houses, ash handling system, feed water treatment, deaeration, evaporation, internal treatment, boiler blow down, steam purity. Condenser, feed water and circulating water systems: Need of condenser, direct contact condensers, feed water heaters, circulating water system, cooling towers, calculations, Numerical Problems	10
Nuclear Power Plants	Chemical and Nuclear reactions, nuclear stability and binding energy, radioactive decay and half-life, nuclear fission, chain reaction, neutron energies. Neutron flux and reaction rates, moderating power and moderating ratio, variation of neutron cross sections with neutron energy, neutron life cycle. Reflectors, Types of Reactor, PWR, BWR, gas cooled reactors. Liquid metal fast breeder reactor, heavy water reactors, Fusion Power reactors, Numerical problems.	10
	Total	40

Text books:
1. Power Plant Engineering - P.K. Nag, Tata McGraw-Hill Publications.
2. Power Plant Engineering - M.M. EI-Wakil, McGraw- Hill Publications.

Gas Dynamics and Propulsion (ME 5123)
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	Introduction of basic fluid mechanics and gas dynamics	2
Compressible flow	Types of compressible flows. The Mach cone. Reference state. One dimensional compressible flow: Variable area isentropic flow, adiabatic flow, flow with friction, normal and oblique shock waves, Prandtl-Mayer expansion.	8
Propulsion fundamentals	Jet Propulsion Fundamentals Steady flow combustion. Ideal Brayton Cycle. Relative Pressure. Turbine cycle examples. Thrust and momentum. Overview of jet engine, review of jet engine design, non-ideal cycle considerations.	10
Propulsion system	Combustion phenomena and combustion chamber performance. Turboprop, Turbofan, Turbojet Propulsion System, Ramjet Thrust and specific fuel consumption.	10
Rocket propulsion system	Ramjet and Rocket Propulsion, Solid propellant rockets: internal Ballistics, basic components, and other features. Liquid propellant rockets: thrust chambers, basic components, and Other features. Turbo-machinery, such as pumps and Turbines, for liquid-propelled rockets. Nuclear and electric Propulsion.	10
	Total	40

Text books:
1. Cumpsty, Nicholas A., Jet Propulsion: A Simple Guide to the Aerodynamic and Thermodynamic Design and Performance of Jet Engines, Cambridge University Press, February 1998
2. Mattingley, Jack D., Elements of Gas Turbine Propulsion, McGraw-Hill, January 1996
3. John, James E. A., Gas Dynamics, Prentice Hall, 2nd ed., March 1984
4. Liepmann, H. W., and Roshko, A., Elements of Gas Dynamics, Dover Publications, January 2002.

Fuel Cell Technology (ME 5124)

For 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 to Fuel cells: Overview	Hydrogen Fuel Cells – Basic Principles, What Limits the Current? Connecting Cells in Series – the Bipolar Plate, Gas Supply and Cooling, Fuel Cell Advantages and disadvantages, Fuel Cell Types, Applications	3
Fuel Cell Thermodynamics	Heat Potential of a Fuel: Enthalpy of Reaction, Work Potential of a Fuel: Gibbs Free Energy, Reversible Voltage of a Fuel Cell under Non-Standard-State Conditions, Thermal and Mass Balances in Fuel Cells, Thermodynamics of Fuel Cells and reversible fuel cells, Efficiency and Efficiency Limits, Fuel Cell Voltage	4
Operational Fuel Cell Voltages	Fuel Cell Irreversibilities – Causes; Activation losses; Fuel Crossover and Internal Currents; Concentration losses;Ohmic Losses	4
Proton Exchange Membrane Fuel Cells	How the Polymer Electrolyte Works, Electrodes and Electrode Structure; Water Management in the PEMFC; PEM Fuel Cell Cooling and Air Supply; PEMFC Electrolyte Materials; PEM Fuel Cell Connection – the Bipolar Plate; Operating Pressure; Reactant Composition, Current status, Few Example Systems integrating PEMFC	6
Alkaline Electrolyte Fuel Cells	Types of Alkaline Electrolyte Fuel Cell, Operating Pressure and Temperature, Electrodes, Cell Interconnections, Current status	4
Direct Methanol Fuel Cells	Anode Reaction and Catalysts; Electrolyte and Fuel Crossover; Cathode Reactions and Catalysts; Methanol Production, Storage, and Safety; Applications	4
Solid oxide fuel cell (SOFC)	How It Works, SOFC Components, Design and Stacking Arrangements; SOFC Performance, Few Example Systems integrating SOFC	5
Molten carbonate fuel cell (MCFC)	How It Works, MCFC Components, Design and Stacking Arrangements; MCFC Performance, Few Example Systems integrating MCFC	5
Environmental Impact of Fuel Cells	Life Cycle Assessment, Important Emissions for LCA, Emissions Related to Global Warming, Emissions Related to Air Pollution; Analysing Entire Scenarios with LCA	5
	Total	40

Text books:

1. Fuel Cell Systems Explained, James Larminie, Andrew Dicks, 2nd Edition, Wiley
2. Fuel cell fundamentals, ryan o'hayre, suk-won cha, whitney g. Colella, fritz b. Prinz, 3rd Edition, Wiley
3. Recent Trends in Fuel Cell Science and Technology, S. Basu, 1st Edition, Springer

Refrigeration and Air-Conditioning (ME 5201)

For 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
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 book.

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

Advanced Heat Transfer (ME 5202)
For 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, Equidimensional (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.	05
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.	05
	SUB TOTAL	14
	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.	03
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.	03
	SUB TOTAL	14
	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	02
15.	Integral methods	01
16.	Turbulence fundamentals	01
17.	Turbulent boundary layers	01
18.	Turbulent flow in ducts	02
19.	Natural convection	01
20.	Boiling	02
21.	Condensation	01
SUB TOTAL		14

TOTAL NO. of Lectures = 42

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

Gas Turbine and Compressor (ME 5203)

For 2nd Semester

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

Sl No.	Topics	No. of lecture periods
01	Introduction to Gas Turbine Cycles: Ideal and actual cycles, Effects of reheating, after-cooling, multi-staging and heat exchanger, Isentropic and polytropic efficiency, Static and stagnation properties of gases	05
02	Principles of Jet Propulsion: Momentum thrust, Pressure thrust, Turbojet engine, Turboprop engine, Supersonic jets and ramjets, Turbofan engine	04
03	Centrifugal compressor: Elements of centrifugal compressor, Flow through centrifugal compressors, Impeller and diffuser, Slip factor, Compressibility effect, Loses in compressor, Centrifugal compressor characteristics, Surging and choking.	07
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 multi stage compressor characteristics, Three dimensional flow, Radial equilibrium theory	07
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.	07
06	Turbine: Introduction, Two dimensional cascade analysis, Work done, Degree of reaction, Losses and efficiency. Multi-staging of Turbine, Vortex flow theory, Turbine cooling	07
08	Matching of Components: Dimensional analysis for component matching, Engine design point operations, Engine off design operations, Engine operating lines	03
	Total	**40**

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.

References Books:

1. S.M. Yahya, Turbines, Compressors and Fans, Fourth Edition, 2011, Tata McGraw-Hill Education Pvt. Ltd.

Solar Thermal Engineering (ME 5221)
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 periods
1.	Solar radiation: Introduction, Sun as the source of radiation, Solar constant, Spectral distribution of extraterrestrial radiation, Variation of extraterrestrial radiation, Classification of solar radiation: Beam solar radiation, Diffuse solar radiation, Global solar radiation	04
2.	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.	03
3.	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.	04
4.	Measurements of solar radiation: Pyranometer, Pyrheliometer, Sunshine recorder, Spectral measurements, Calibration and standardization of measuring instruments	03
5.	Solar thermal applications: Basic overview of solar collectors, 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	03
6.	Overview of solar collectors, Flat Plate Collector, Collector Efficiency Factor and Collector Heat Removal Factor, Collector Testing, Factors influencing the performance of Flat Plate Collector	05
7.	Solar Air Heater and its Analysis	04
8.	Concentrated Solar Collectors, Aperture ,Concentration Ratio, Tracking of Collectors and methods of tracking, Compound Parabolic Collectors, Parabolic Trough Collectors, Heliostats	07
9.	Economic analysis of solar collectors, Computation of payback period, Life cycle cost analysis.	04
	Total	37

Text Books:

10. Solar Energy Fundamentals and Applications by H. P. Garg and J. Prakash, Tata Mc Graw-Hill Publishing Company Limited.
11. Solar Energy Fundamentals, Design, Modelling and Applications by G. N. Tiwari, Narosa Publishing House.

Reference Books:

1. Solar Energy: Principles of Thermal Collection and Storage by S. P. Sukhatme and J.K.Nayak, Tata Mc Graw-Hill Publishing Company Limited.
2. Solar Engineering of Thermal Processes by John A. Duffie and William A. Beckman, John Wiley and Sons, Inc.

Numerical Heat Transfer (ME 5222)
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 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	05
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	10
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	10
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.	09
6.	Introduction to commercial CFD codes.	04
Total		42

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

Greenhouse Technology (ME 5223)
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. Introduction	History and types of greenhouse; importance, function and features of green house; scope and development of greenhouse technology. Location, Planning and various component of greenhouse.	8
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.	8
3. Greenhouse environment regulations	Greenhouse heating, cooling, shedding and ventilation systems; Carbon Dioxide generation and monitoring and lighting systems, instrumentation & computerized environmental Control Systems.	8
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; postproduction quality and handling Cost analysis of greenhouse production.	8
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.	8
	Total	40

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.

3. Protected Cultivation of Vegetable Crops. Balraj Singh, Kalyani Publishers.

Cryogenic Systems and Equipment (ME 5224)
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	Introduction to Cryogenic Systems: Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures.	5
Gas Liquification 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 Regrigerated Hydrogen Liquefaction Systems. Critical components in Liquefaction Systems, Introduction to air separation.	11 2
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.	8
Cryogenic Insulation	Cryogenic Insulation, Multi-layer insulation, Vacuum insulation etc. Applications: Applications of Cryogenic in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications.	8
Vacuum Technology	Basic Theory, Gas surface interactions: physisorption, chemi-sorption, condensation, Vacuum Pumps, Vacuum Applications: Freeze drying, packaging, vacuum coating, microelectronics, particle accelerators, distillation, metallurgical processes, television and X-ray tubes, cryogenic insulation, space simulation	8
	Total	42

Text books:

1. *Cryogenic Systems*, R. F. Barron, McGraw Hill, 1985.
2. *Cryogenic Process Engineering,* K. D.Timmerhaus and T.M. Flynn, Plenum Press, 1989
3. *Fundamentals of Cryogenic Engineering,* M Mukhopadhyay, PHI Learning Pvt. Ltd., New Dlehi, 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.

Nuclear Power Engineering (ME 5225)
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. 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.	9
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.	9
3. Reprocessing	Nuclear Fuel Cycles - Spent Fuel Characteristics - Role of Solvent Extraction in Reprocessing Solvent Extraction Equipment.	9
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.	9
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.	9
	Total	45

Text Books:

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

2. Collier J.G., and Hewitt G.F, "introduction to Nuclear power", Hemisphere publishing, New York, 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/).

Alternative Energy (ME 5226)
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 Lectures
1.	Introduction: Perspective, Renewables, Environmental impacts of conventional power plants, Advanced technologies for cleaner power from fossil fuels, Direct energy conversion devices	2
2.	Solar Power: Solar geometry, radiation on inclined surfaces and tilt fctors, 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	06
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	06
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	04
5	Thermoelectric devices - Working principles, descriptions, emf and figure of merit, efficiency calculations.	04
6.	Biomass energy conversion: Bio-gasification, gas engines, biomass gasification combined cycles (BIGCC).	04
7.	Pumped hydro plants: Principle of operation, Load fluctuations and load leveling, load curve analysis	04
8.	Wind Energy Conversion. Principle of conversion, Types of turbines.	04
9.	Tidal, Wave and Ocean Thermal (OTEC) energy conversion: Basic principles, Description of different types of plants, open and closed OTEC systems	04
10	Geo-thermal energy - Principle of Conversion, geothermal resources, classification of plants.	04
Total		**42**

Recommended References

9. Principles of Energy Conversion - Culp
10. Non-Conventional Energy - B H Khan
11. Solar Energy by S P Sukhatme
12. Fuel Cell Systems Explained - Larminie & Dick

Design of Thermal Systems (ME 5227)
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	Definition of Engineering Design, Design as Part of Engineering Enterprise,Thermal Systems,	2
Basic Considerations in Design	Formulation of the Design Problem, Conceptual Design, Steps in the Design Process, Computer-Aided Design, Material Selection	2
Modeling and Simulation of Thermal Systems	Types of Models,Mathematical Modeling, Physical Modeling and Dimensional Analysis, Curve Fitting, Numerical Modeling, Solution Procedures, Numerical Model for a System, System Simulation, Methods for Numerical Simulation	6
Acceptable Design of a Thermal System	Initial Design,Design Strategies, Design of Systems from Different Application Areas,Design of Components Versus Design of Systems, Additional Considerations for Large Practical Systems	7
Economic Considerations	Calculation of Interest,Worth of Money as a Function of Time,Series of Payments,Raising Capital,Taxes,Economic Factor in Design,Application to Thermal Systems,Summary, Problems	5
Methods for Optimization	Basic Concepts,Optimization Methods,Optimization of Thermal Systems,Practical Aspects in Optimal Design, Geometric Programming, Linear Programming,Dynamic Programming	5
Lagrange Multipliers	Introduction to Calculus Methods,Optimization of Unconstrained Problems,Optimization of Constrained Problems,Applicability to Thermal Systems	4
Search Methods	Basic Considerations,Single-Variable Problem,Unconstrained Search with Multiple Variables,Multivariable Constrained Optimization,Examples of Thermal Systems,Summary, Problems.	5
Knowledge-Based Design and Additional Considerations	Knowledge-Based Systems,Additional Constraints,Professional Ethics,Sources of Information,An Overview of Design of Thermal Systems,Summary,Problems	4
	Total	40

Text books:

1. Design and Optimization of thermal systems, Second Edition© 2008 by Yogesh Jaluria, Taylor & Francis Group, LLC, CRC Press is an imprint of Taylor & Francis Group, an Informa business.
2. Optimization of Engineering Design – Kalyanmoy Deb – PHI
3. Optimization Concepts and Applications in Engineering by A.D. Belegundu and T.R. Chandrapatla, Pearson Education Asia, 2002.

Reference books:

1. Design of thermal systems – W.F. Stoecker -Third Edition, Mc Graw Hill.
2. Thermal Design and Optimization, Adrian Bejan, George Tsatsaronis, Michael Moran, John Wiley and Sons, 1995.

Course Contents for Machine Design Specialization

Advanced Solid Mechanics (ME 5106)

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
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:	34

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. Tomoshenko and J. N. Goodier, McGraw Hill International
4. Advanced strength of materials by Den Hartog, McGraw Hill

Mechanical Vibration (ME 5107)
For 1st Semester

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

Module	Topics	No. of Lecture Periods
1. Introduction	Degrees of freedom Lumped parameter modeling of systems Lagrange equation	4
2. single degree-of-freedom model	Free vibration Forced vibration Damped vibration Resonance Vibration isolation	5
3. Two/multi degrees of freedom model	Mass and stiffness and damping matrix Eigen value problem in vibration Modes of vibration Modal decomposition method of forced vibration	10
4. Vibration of elastic bars and shafts	Equation of motion Natural frequency and mode shapes under different boundary conditions	10
5. Vibration of elastic beams	Euler-Bernoulli beam Equation of motion Natural frequency and mode shapes under different boundary conditions Forced vibration using modal decomposition	13
Total		42

Text Book:

1. Mechanical Vibration, S. S. Rao, 5th ed. , Prentice Hall

Reference books:

1. Principles of Vibration, B. H. Tongue, Oxford University Press (Indian edition).

Engineering Tribology (ME 5108)
For 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 periods
01	Introduction: a brief history of Tribology, industrial importance	02
02	Engineering surfaces - properties and measurement: surface profilometer, optical microscopy, electron microscopy, statistical and fractal description of surface roughness	06
03	Contact between surfaces: geometry of non-conforming surfaces in contact, surface tractions, surface and subsurface stresses, contact of rough surfaces	06
04	Adhesion at solid-solid contact: adhesion models, factors influencing adhesion, adhesion at the contact between rough surfaces	04
05	Genesis of solid friction, friction theories - simple adhesion theory, modified adhesion theory, deformation theory, measurement tools, friction of metals and non-metallic materials	06
06	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
07	Thermal considerations in sliding contact: measurement of surface temperature in sliding, theoretical analyses	04
08	Tribo-testing tools: measurement of friction and wear	02
09	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 (ME 5131)
For 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 Lecture
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 octahydral plane (b) Strain displacement relation, Compatibility condition. (c) Stress Strain relation, Generalised Hook's Law (d) Equilibrium equation 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 coordinate ii) polar co-ordinate.	05
3.	Strain Energy	Concept of strain energy, Principle of virtual work, Solution of 2D elasticity problem using principle of virtual work	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 solution of plasticity problem without hardening (elastic- perfectly plastic material)	i)Bending of prismatic beam ii)Torsion of prismatic bar iii)Thick cylinder with internal pressure	05
8.	Plane strain problem	i) Slip line theory and its application Ii) Solution of 2D metal forming problem using 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
No of Lecture (1 hr duration)			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 (ME 5132)
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 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.

Biomechanics (ME 5133)
For 1st 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 Biomechanics: Basic terminology, concept and function of human musculoskeletal system, musculoskeletal anatomy, review of statics and dynamics.	06
2.	Biomechanics of musculoskeletal system – composition, structure and biomechanical behaviour of bone, cartilage, muscle, ligament and tendon.	07
3.	Biomechanics of Joints – structure, range of motions and musculoskeletal model of forces for human joints (hip, knee, ankle, shoulder, elbow and spine).	07
4.	Lubrication and wear of human joints.	04
5.	Joint replacement and fracture fixation – stress analysis, design approach of artificial joints (hip, knee, ankle, shoulder, elbow and spine), failure mechanisms, bone remodelling, fracture healing.	08
6.	Human motion and gait analysis: Review of linear and angular kinematics, kinetic equation of motion, kinematic measurement techniques, gait cycle, engineering approaches to gait analysis, example applications.	08
	Total	**40**

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.

Finite Element Methods (ME 5134)
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
Fundamental concepts of FEM	Basic concepts of the Finite Element Method. Versatility of FEM and its use in different applications. Review of matrix theory and numerical solution of linear algebraic equations.	1-3 (3)
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 a 1-D linear and quadratic element. Natural coordinates. Weak form over a typical element. Element equation, assembly and solution for PV and SV.	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.	24-29 (6)
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.	30-35 (6)
FE formulation and solution of 2D steady state vector field problems	Stress analysis problems: Plane stress and plane strain type in 2D. Review of equilibrium equation, stress-strain and strain-displacement relation. Variational formulation of stress analysis and heart transfer problems and derivation of their functional.	36-40 (5)
	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. An introduction to the Finite Element Method (3rd Edition), by J.N. Reddy, Tata McGraw-Hill, 2005.
2. Finite Element Analysis Theory and Application with ANSYS (4th edition), by Saeed Moaveni, Pearson, 2015
3. Introduction to Finite Elements in Engineering, by T.R. Chandrupatla and A.D. Belegundu, Prentice-Hall of India Pvt. Ltd., 1991.

Design Optimization (ME 5135)

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	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 probelm	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 optimizationb 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.

Fatigue, Creep and Fracture Mechanics (ME 5206)
For 2nd Semester

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

Module	Topics	Number 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) - Hysterisis loop, steady-state loop, cyclic stress - strain curve, Coffin - Massion equation, fatigue ductility coefficient and fatigue ductility exponent, total strain life curve (Morrow's equation), Mean stress correction - (i) Morrow's method (ii) Smith Watson Topper's method (c) Fatigue damage accumulation and life exhausion, Linear damage rule (Palmgreen Miner Rule), cycle counting methods	12
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	08
Fracture	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 characterising 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	12
	Total :	32

Text books:

1 Fatigue of Metals - S. Suresh
2. Fundamental of creep in metals & alloys - M. E. Kassner
3. Elementary Fracture Mechanics - David Broek
4. Elements of Fracture Mechanics - Prasanta Kumar

Geometric Modelling For CAD (ME 5207)
For 2nd Semester

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

Sl No.	Topics	No. of lecture periods
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

Nonlinear Dynamics (ME 5208)
For 2nd Semester

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

Module	Topics	Number of Lectures
Introduction	Properties of Linear systems, Understanding Nonlinearity, Introduction to Flows and Maps, Autonomous and Non-autonomous Systems, Sources of Nonlinearity, Linear and Nonlinear Springs, Examples of Different Nonlinear Oscillators, Non-dimensionalization.	2
Geometric Understandings	Issues with Closed Form Solution, State/Phase Space, Fixed Points. Stability: Lyapunov, Asymptotic, Exponential. Second Order Conservative Systems: Duffing and Other Oscillators.	4
General Two Dimensional Systems	Linearization, Linear Stability Analysis of Fixed Points. Structural Stability, Time-Reversal Symmetry. Understanding Higher Dimensional Linear Systems Using 2D Linear Systems.	7
Limit Cycle	Definition, Van der Pol Oscillator, Existence and Non-existence of Limit Cycle.	2
Approximate Methods	Order Symbols, Convergent and Asymptotic Series. Regular and Singular Perturbations of Algebraic Equations. Regular Perturbation of ODE, Poincaré- Lindstedt Method, Method of Multiple Scales, Averaging Method, Harmonic Balance, Galerkin Projections.	12
External Excitation	The Forced Duffing Oscillator: Backbone Curve, Jump Phenomenon and Hysteresis. The Forced van der Pol Oscillator: Entrainment.	3
Parametric Excitation	Mathieu's Equation, Hill's Equation, Floquet Theory, Effect of Damping.	5
Bifurcations	Static Bifurcations: Turning Point, Transcritical, Pitchfork. Dynamic Bifurcation: Hopf.	4
A brief Introduction to Chaos	One Dimensional Map: Fixed Points and their Stability. Numerics with Logistic Map, Lorenz Equations. Definition of Chaos, Lyapunov Exponent, Poincaré Map.	3
	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. A. H. Nayfeh, Perturbation Methods, John Wiley and Sons, New York, 2000.

Bearing Lubrication (ME 5231)
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
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 lubricatiuon (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)

Dynamics and Control of Mechanical Systems (ME 5232)
For 2nd Semester

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

Module	Topics	No. of Lecture Periods
6. Introduction	Frequency domain modeling of linear systems Transfer functions Block Diagram Poles and zeros of a system	4
7. Transient response of linear systems	First second and higher order systems Impulse, step and ramp response	5
8. Frequency response of linear systems	Bode plot , Nyquist plot, Nichols plot bandwidth	5
9. closed-loop characteristics of systems	Sensitivity to modeling error Disturbance/ noise rejection Steady state accuracy Stability	7
10. Root locus		3
11. Modern control	State-space representation Controllability and observability Lyapunov stability	7
12. Active control of m/c tools	CNC m/c tolls control	5
13. Active vibration control	Stability of second order systems Direct velocity feedback Acceleration feedback control Positive position feedback control	6
Total		42

Text Book:

1. Control system Engineering, 4th ed., Norman. N. Nise

Reference books:

1. Principles of Passive and Active vibration Control, A. K. Mallik and S. Chatterjee, East-west press

Composite Materials (ME 5233)
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
Composite Materials: Definition, Classification	Definition of fibre 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, minimum and critical volume fraction	03
Fabrication of Composite Materials	Manufacturing of composites: laminate casting, helical winding, polar winding and pultrusion process	04
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	06
Theories of Failure of Orthotropic Laminae	Theories of failure for orthotropic lamina, bi-axial strength theories	04
Environmental effects on composites	Environmental effects on composites: thermal and hygrothermal effects	03
Analysis of Composite Laminates	Introduction to composite laminates, lamination code, classical lamination theory based on Kirchhoff's hypothesis	06
Analysis of Composite Laminates (Cont'd)	Specially orthotropic, generally orthotropic, symmetric, anti-symmetric and quasi-isotropic laminates	03
Progressive Failures of composite laminates	Design consideration: analysis of laminates after first ply failure, interlaminar stresses	03
Property Determination of Composites by Experiments	Experimental characterization of composites: tension, compression tests, various types of in-plane shear tests and flexural tests	05
	Total	40

Text Books

1. Analysis and Performance of Fiber Composites (Second 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, 2011.

Design of Piping Systems (ME 5234)
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	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.

Industrial Tribology (ME 5235)
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
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 tribofailures	05
05	Wear debris analysis: Ferrography 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	Greentribology: 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

Mechanical Drive and Control (ME 5236)
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	Introduction to automatic control, historical developments, system representation, Control system elements.	3
Representation of Drives and Control Components	Translational mechanical components, rotational components, electrical components, hydraulic components.	4
System Modelling	System modeling: Frequency response, Mechanical system, electrical system, Thermal system, Fluid system. Actuators- Electric motors; D.C. Motors, Stepper motor, , Hydraulic actuators, Pneumatic actuators Transducer and Sensors : Principles, difference between transducer and sensors, transducer types – photo emissive, photo conductive, photovoltaic, thermistors, Thermocouple, Inductive, capacitive, Peizoelectric.	10
Representation of Control systems	Hydraulic and Pneumatic control systems, temperature control system, speed control system, feedback control systems	5
Control Theories	State-Space, Laplace and frequency domain system behavior; Bode, Nyquist, Frequency response method and root-locus plots; open and closed loop control systems; stability and sensitivity	10
System Performance and Application	Hydraulic systems. Pneumatic systems, Gyroscopic systems Electrical systems. Inertial guidance, Attitude control, Some case studies.	8
	Total	40

Text books:
1. Introduction to Dynamics and Control in Mechanical Engineering Systems, 1st Edition, by Cho.W.S.To, ASME press, Wiley Publication., 2016.
2. Control Systems Engineering, 6th Edition, by N.S. Nise, (With CD). John Wiley &Sons. 2007.
3. Mechatronics, N.G. P.C Mahalik, Tata McGraw Hill.
4. Mechatronics, A.Smaili& F Mrad, Oxford University Press.

Non-Destructive Testing of Materials (ME 5237)
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
I.	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
II.	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
III.	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
IV.	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
V.	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
VI.	Radiography Testing (RT)	Principle, electromagnetic radiation sources: X-ray source, production of X-rays, high energy X-ray source, gamma ray source - Properties of X-rays and gamma rays Inspection techniques like SWSI, DWSI, DWDI, panoramic exposure, real time radiography, films used in industrial radiography, types of film, speed of films, qualities of film screens used in radiography, quality of a good radiograph, film processing, interpretation, evaluation of test results, safety aspects required in radiography applications, advantages and limitations of RT.	7
VII.	Infrared	Introduction and fundamentals to infrared and thermal testing,	6

	Thermography 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.	
VIII.	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).

Course Contents for Manufacturing science Specialization

Advanced Theory of Metal Cutting (ME 5111)

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
Geometry of cutting tools	Geometry of cutting tools; turning, milling and drilling - in different reference systems.	8
Mechanism of chip formation	Mechanism of chip formation by single point tools, drills and milling cutters. Types of chips and their characteristics. Criticism of single shear plane theory. Effective rake angle.	8
Mechanics of machining	Mechanics of machining, theoretical estimation of cutting forces and power consumption.	6
Thermodynamics of machining	Thermodynamics of machining, sources of heat generation, cutting temperature.	6
Cutting tools	Cutting tools: methods of failure, mechanics of tool wear, essential properties, assessment of tool life and cutting tool materials.	4
Cutting fluids	Cutting fluids: purpose, essential characteristics, selection and methods of application.	2
Causes of vibration	Causes of vibration and chatter in machining and their remedy.	2
Economics of machining	Economics of machining: principal objectives, main parameters and their role on cutting forces, cutting temperature, tool life and surface quality, selection of optimum combination of parameters	6
	Total	42

Text books:

1. Machining and Machine Tools – A. B. Chattopadyay, Wiley India Pvt. Ltd., New Delhi.
2. Materials and Processes in Manufacturing – E.P. DeGarmo, J. T. Black and R.A. Kohser., Prentice Hall of India Pvt. Ltd., New Delhi.
3. Metal Cutting Principles – M.C. Shaw, Oxford University Press, Indian Addition, Kolkata**.**

Reference Book:

1. Production Technology – HMT, Tata Mc Graw Hill, New Delhi.
2. Manufacturing Processes –S. Kalpakjian, S.R. Schmid, PEARSON, New Delhi.

Non-Traditional Machining (ME 5112)

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 (ME 5113)

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:

4. Manufacturing Technology (Foundry, Forming and Welding) – by P N Rao, Tata McGraw-Hill (I) Publishing Company Limited, New Delhi.
5. Manufacturing Science by A. Ghosh and A. K. Mallick, 2e, Affiliated East-West Press Pvt. Ltd.
6. Welding and Welding Technology by Richard L Little, Tata McGraw-Hill (I) Publishing Company Limited, New Delhi.

Reference Books:

7. Laser Material Processing by W.M. Steen, Springer-Verlag.
8. Modern Machining Processes by P.C. Pandey and H.S. Shan, Tata McGraw-Hill Publishing Company Limited.
9. Production Technology, HMT, Tata McGraw-Hill Education.

Industrial Engineering (ME 5141)

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
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:

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

Design of Production System (ME 5142)

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*

Computer Integrated Manufacturing Systems (ME 5143)

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	Introduction to CAD/CAM, CIM, Evolution of CIM, hardware and software to be used in CIM, Data base requirements in CIM, Computer Networking, CIM wheel, Major elements of CIM system, Three step process for implementation of CIM, Computers in CIM, Management of CIM, Product Design and Development Cycle, Advanced modelling techniques, Design for Manufacturing & Assembly	8 L
Automated Manufacturing Systems & inspection	Automated production line, system configurations, work part transfer mechanisms, Fundamentals of Automated assembly system, System configuration, Part delivery at workstations, Design for automated assembly, Overview of material handling equipment, Consideration in material handling system design, The 10 principles of Material handling. Storage systems, Overview of Automated Identification Methods, Bar Code Technology, Radio Frequency Identification, Optical Character Recognition, and Machine Vision.	8 L
Group Technology and FMS	Part families, Parts classification and coding, Production flow analysis, Grouping of parts and Machines by rank order clustering method, Benefits of GT, FMS, Dedicated and random order FMS, Components, workstations, FMS layout configurations, Computer control systems, FMS planning and implementation issues, Architecture of FMS, flow chart showing various operations in FMS, Machine cell design, Composite part concept, Holier method, Key machine concept, Quantitative analysis of FMS, Bottleneck & Extended Bottleneck model, sizing the FMS, FMS applications & benefits	8 L
Industrial Robotics	Definition, Law of Robotics, Anatomy of a Robot, Robot Classification, Geometric Configurations, Robot Specifications. Actuators: Electric and Hydraulic and Pneumatic. Types of Robot Grippers: Mechanical, Pneumatic and Magnetic. Different Gripping Mechanisms. 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.	9L
Types of Process Control and Automatic Data Capture	Introduction to process model formulation, linear feed back control systems, Optimal control, Adaptive control, Sequence control and PLC. Computer process control, Computer process interface, Interface hardware, Computer process monitoring, Direct digital control and Supervisory computer control. Overview of Automatic identification methods, Bar code technology, Other Automatic data capture technologies.	6 L
Challanges	External and Internal challenges prior or during application of CIM, World-class order winning criteria, CIM Implementation & Barriers	3 L
	Total Classes	42 L

Text books

1. Computer Integrated Manufacturing by Joseph Harrington, Industrial Press
2. Automation, Production Systems and Computer Integrated Manufacturing, M.P. Groover, Pearson Education, Prentice Hall of India Pvt. Ltd
3. Kant Vajpayee, S., ―Computer Integrated Manufacturing‖, Prentice Hall of India, New Delhi
4. James A. Retrg, Herry W.Kraebber, ―Computer Integrated Manufacturing‖, Pearson Education, Asia
5. Gideon Halevi and Ronald D. Weill, ―Principles of Process Planning‖, Chapman Hall

Reference books

6. Anderson, D.M., "Design for manufacturability & concurrent engineering: how to design for low cost, design in high quality, design for lean manufacture, and design quickly for fast production," CIM press
7. Alavudeen and Venkateshwaran, ―Computer Integrated Manufacturing, PHI Learning Pvt. Ltd., New Delhi
8. Viswanathan, N., and Narahari, Y., ―Performance Modeling and Automated Manufacturing Systems, Prentice Hall of India Pvt. Ltd
9. Radhakrishnan, P., Subramanian, S., and Raju, V., ―CAD/CAM/CIM‖ New Age International Publishers
10. Jaya Krishna S, Product Lifecycle Management: Concepts and cases, ICFAI Publications
11. SOA approach to Enterprise Integration for Product Lifecycle, IBM Red books

Quality Engineering (ME 5144)

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.

Statistical Methods for Engineers (ME 5145)

For 1st Semester

Credit – 3 **Full Marks: 100**

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

Module	Topics	No. of Lectures
Fundamentals of Experimentation	Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation	2
Simple Comparative Experiments	Basic concepts of probability and statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA	4
Principles Components Analysis	Objectives of Principal Components Analysis, Principal Components Analysis on the Variance, Covariance Matrix, Principal Component Scores and estimation, Component Loading Vectors	5
Experimental Designs	1-way and 2-way classifications, Completely randomized and randomized block design, Factorial designs, fractional factorial designs, central composite design, standard orthogonal arrays and interaction tables, data analysis	7
Regression analysis	Linear regression, least square estimation, generalized least squares, multiple regression, testing general linear hypothesis	4
Reliability estimation	The exponential, Weibull models, estimation of reliability for these models	4
Testing of hypothesis	Fundamental notions, tests based on normality, non- parametric procedures – Chi-square tests of goodness of fit, Wilcoxon, testing of hypothesis based on exact sampling distributions - chi square, t and F	7
Response Surface Methodology	Concept, linear model, steepest ascent, second order model, Regression models	4
Taguchi's Parameter Design	Concept of robustness, noise factors, objective function & S/N ratios, inner-array and outer-array design, data analysis	5
	Total Classes	42

Text books:

1. Montgomery and Peck: Introduction to linear regression analysis, 4th Edition, Wiley Inter science
2. Mendenhall, W., and Sincich, T., Statistics for Engineering and the Sciences, 6 th edition, CRC Press
3. Johnson, D.E.: Applied Multivariate Methods for Data Analysis. Duxbury, USA
4. Hogg, R. V., and Tanis, E. A., Probability and Statistical Inference, 9th edition, Prentice Hall
5. Rohatgi, V.K.: An Introduction to Probability Theory and Mathematical Statistics, John Wiley and Sons
6. Johnson, R.A., Miller, I and Freund J., "Miller and Freund's Probability and Statistics for
7. Engineers", Pearson Education, Asia, 8th Edition

Reference books:

1. Field, A., Discovering Statistics Using SPSS, 4th edition
2. Carlin, B. P., and Louis, T. A., Bayesian Methods for Data Analysis, 3rd edition, CRC Press
3. Srivastava, M.S.: Methods of Multivariate Statistics, John Wiley, New York,

Energy-Beam Processing of Materials (ME 5211)

For 2nd Semester

Credit – 3 **Full Marks: 100**

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

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 (ME 5212)

For 2nd 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.	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 (ME 5213)
For 2nd 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.	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.

Quantitative Techniques in Production Management (ME 5241)

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 (ME 5242)

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,	4 L

	probability of project completion by a target date, Project crushing. 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 (ME 5243)

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
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 (ME 5244)

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
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 (ME 5245)

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.*

Industrial Automation (ME 5246)

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	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.*

Advanced Machining Technology (ME 5247)

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

Course Contents for Open Electives

Renewable Energy (ME 5161)

For 1st Semester

Credit – 3 **Full Marks: 100**

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

Serial No.	Topics	No. of Lectures
1.	Introduction: Conventional & non-conventional energy sources	4
2.	Solar energy: radiation measuring instrument, Basics of Flat plate collectors, Concentrators Solar Principle of photovoltaic conversion of solar energy. Application of solar energy.	6
3.	Wind energy: characteristics and measurement, Wind energy conversion principles, Types and classification of WECS.	6
4.	Biomass Energy: Classification of biomass. Physicochemical characteristics of biomass as fuel. Biomass conversion routes.	6
5	Small Hydropower: Overview of micro, mini and small hydro system, types of hydro turbine; Ocean Energy, Principle of ocean thermal energy conversion system, Principles of Wave and Tidal energy conversion.	6
6.	Geothermal energy: Origin of geothermal resources, type of geothermal energy deposits.	6
7.	Hydrogen as a source of energy. Types of fuel cell, fuel cell system	6
Total		**40**

Recommended References

13. Non-Conventional Energy - B H Khan
14. Solar Energy by S P Sukhatme
15. Fuel Cell Systems Explained - Larminie & Dick
16. Renewable Energy by Godfrey Boyle
17. Renewable Energy Resources by John Twidell and Tony Weir

Industrial Robotics (ME 5261)
For 2nd Semester

Credit – 3 **Full Marks: 100**

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

Module	Topics	Number of Lectures
Introduction	Definition, Law of Robotics, Anatomy of a Robot, Robot Classification, Geometric Configurations, Robot Specifications.	2
Robot Drive System and Robot End Effectors	Actuators: Electric and Hydraulic and Pneumatic. Types of Robot Grippers: Mechanical, Pneumatic and Magnetic. Different Gripping Mechanisms.	4
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.	10
Differential Motion and Velocity	Differential Motions of Frames and Robot Joints, Robot Jacobian, Inverse differential Kinematics.	2
Robot Control	Open and Closed Loop Systems, Linear Control, Equation of Motion of Multi-DOF Manipulators, Introduction to Manipulator Control.	9
Different Sensors	Internal Sensors: Position, Velocity and Acceleration. External Sensors: Range Sensors, Proximity Sensors, Touch Sensors, Force/Torque Sensors.	4
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. Cartesian Space Scheme: Straight Line Path, Circular Path.	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.	2
	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.